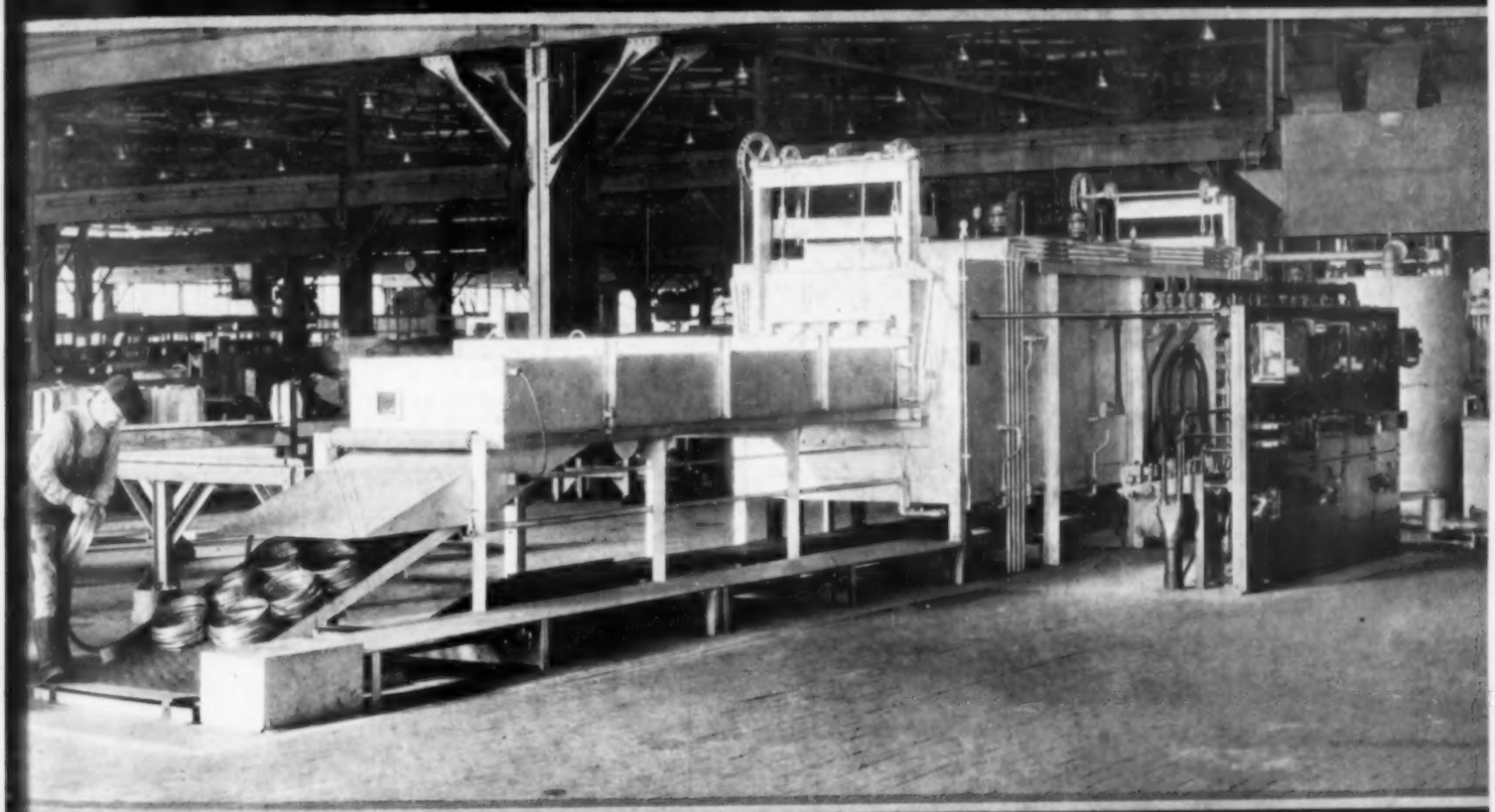
METAL PROGRESS



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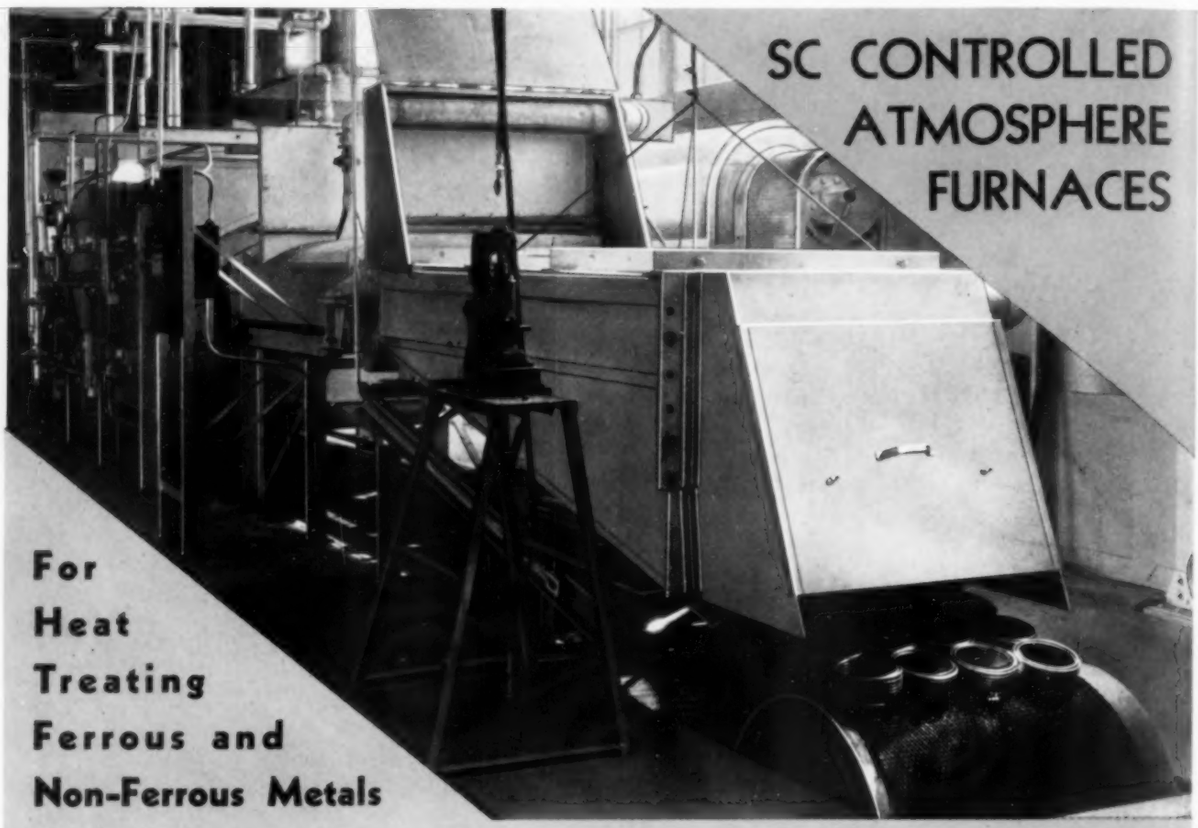

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Above: SC Continuous belt muffle type furnace installation for bright annealing copper and brass tubing in straight lengths and coils.

Below: SC Standard DX gas preparation unit for supplying controlled atmosphere gases to furnace shown above. These units are available separately for application to existing furnaces.

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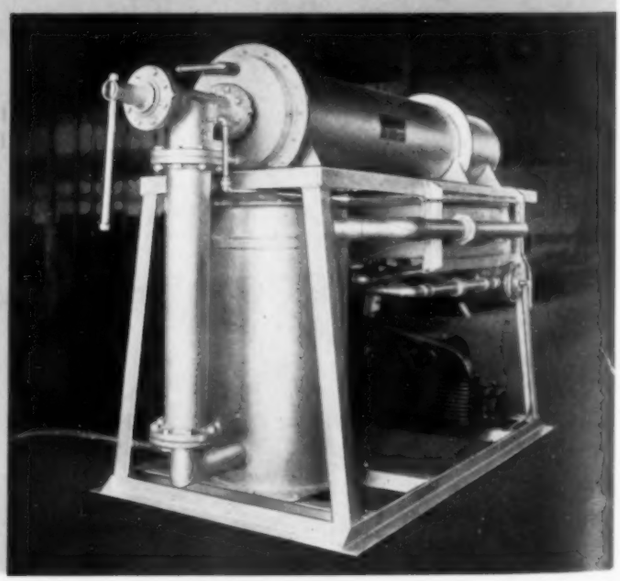

Surface Combustion Corporation

(SC) TOLEDO, OHIO

Sales and Engineering Service in Principal Cities

June, 1934
Volume 25, No. 6

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Ernest E. Thum, Editor

Metal Progress

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The cover photograph represents the charging end (with control mechanism at right) of a muffle furnace for bright annealing copper tubes, installed in the Cleveland plant of Chase Brass & Copper Co. by Electric Furnace Co. of Salem, Ohio.

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Our distinguished correspondent from France, Professor Albert M. Portevin, has specialized for a long time in metallography and physical metallurgy, solving in these years many problems in heat treatment and foundry practice. In addition to his teaching duties he finds time to serve as one of the editors of Revue de Metallurgie and as consulting engineer to several French and Belgian firms. He has been honored by the presidency of Societe des Ingenieurs Civils de France, their leading engineering association.

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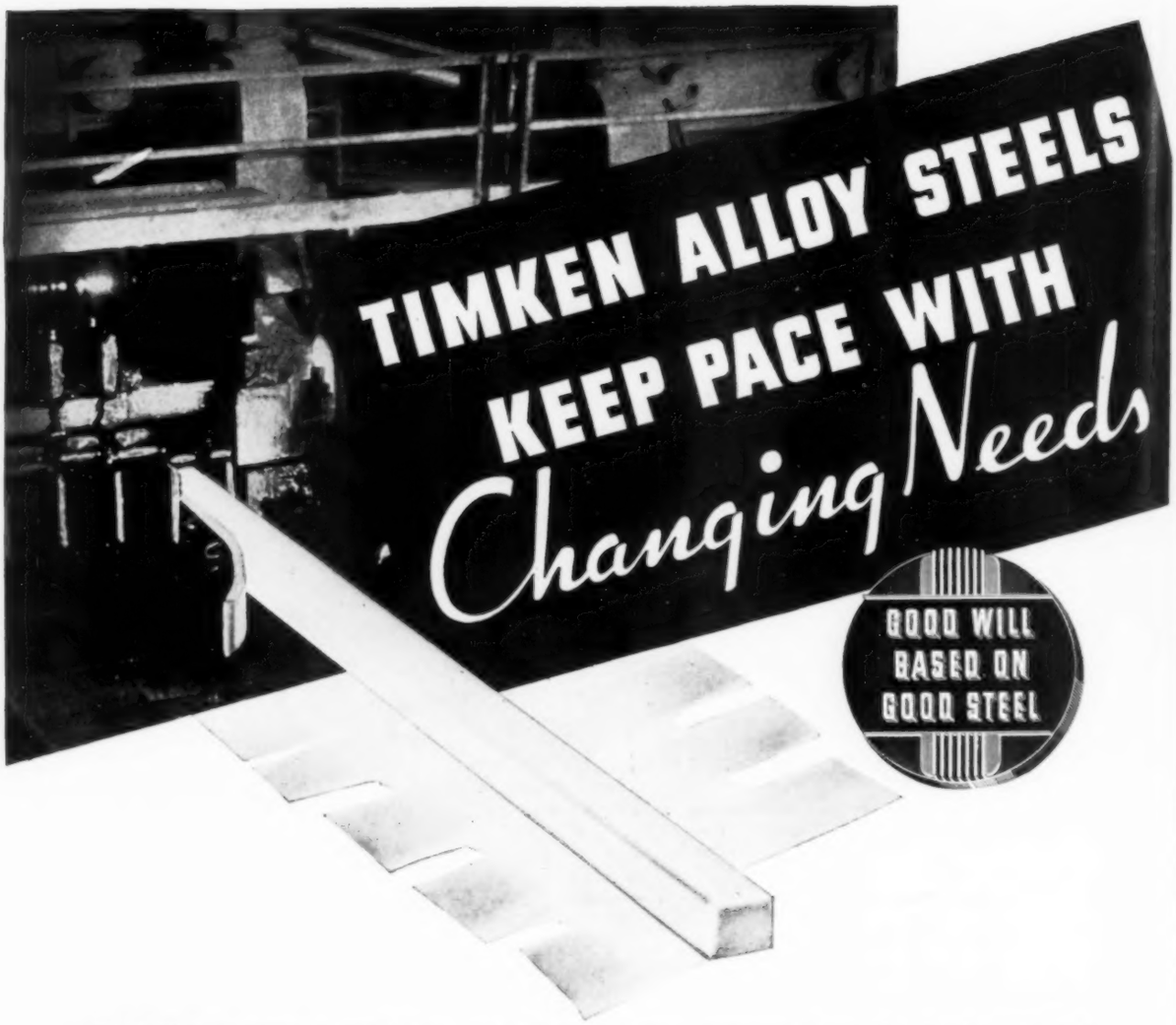

DESIGNS, operating conditions and load requirements have undergone radical changes during the last few years in all types of machinery, necessitating revised specifications in material—principally steel.

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NRA

New requirements for copper alloy tubes

by D. K. Crampton
Director of Research
Chase Brass & Copper Co.
Waterbury, Conn.

RECENT years have seen a consistent demand for increasingly higher quality and longer lived copper alloy tubes. Coincidentally, there has been an increase in the severity of conditions to which these materials are subjected. As a result of these two trends, the tube manufacturer has been confronted with the problem of improving his products and often the processes by which they are fabricated. It will be my aim to describe the present demands for tubing by several important consuming industries, responsible for this progress.

Plumbing Pipe

There are a number of causes contributing to the more severe service conditions to be met by hot or cold water systems in residences and office buildings. The first of these causes has to do with the source of the water, independent of its treatment, and is associated with the increasing use of deep driven wells for water supplies. Deep well waters usually are more corrosive than surface waters.

Other causes of increased corrosion result from water treatments. In many localities where the water has a high temporary hardness, a softening treatment is resorted to, and in general, any water is more corrosive after softening than it was before. Another treatment is aëration; from the standpoint of potability this is, of course, highly desirable, but all other things being equal, a highly aërated water is markedly more corrosive. A third treatment making for more corrosive water is filtration, which removes those organic materials tending to form a slimy protective film on the inside pipe surfaces.

Finally, using alum in mechanical filtration lowers the pH (hydrogen ion concentration) and increases the free carbon dioxide with a consequent increase of corrosivity.

There are two additional conditions relating to the installation methods which tend to give trouble, and are independent of the source or treatment of the water. First, there is an increasing use of circulating systems in hot water lines, which means that the temperatures

run continuously and markedly hotter than in ordinary dead-end systems. It is common knowledge that the corrosiveness of water increases with increasing temperature. Second is the effect of grounding various electrical circuits on water lines. This has only recently been carefully investigated. While the effect of such grounding on corrosion, in the sense of reducing the life of the pipe, is in all probability negligible, there is evidence that such grounding does cause objectionable tastes and odors, and possibly accelerates discoloration and staining of fixtures.

Brass Almost Ideal

Some years back, when brass pipe first obtained general recognition and use for plumbing purposes, it was felt that here was the ultimate material. While a very marked improvement in service was generally found as compared to less resistant materials, time showed that the problem had not been entirely solved. The early brass pipe was usually muntz metal (60% copper, 40% zinc). Structurally it consisted of both alpha and beta phases, and due to this duplex microstructure it proved to be less corrosion resistant than had been hoped — at least in very corrosive waters. Dezincification in localized areas along the pipe, and more frequently at the joints, caused some premature failures.

From the first, some high brass (65 to 70% copper, balance zinc) was used along with the muntz metal, and in a great majority of cases this performed markedly better. Dezincification in all types of cold waters was largely eliminated, although with hot waters the improvement was less noticeable. For a while high brass was therefore the preferred pipe, but with increasing tendency toward circulating hot water lines and high temperatures there were still too many failures.

As a result of wide service experience and many laboratory and installation tests, it became apparent that brasses with still higher copper content would overcome this serious dezincification. Admiralty alloy, low brass, red brass, pure copper, and tin coated materials have all been investigated in the laboratory and tried more or less extensively in practice, and of all these, red brass (85% copper, 15% zinc) now appears to be distinctly the most promising for the widest range of conditions. This alloy does not dezincify in any water nor at any temperature. To be sure, copper pipe cannot dezincify, but it has been found that it sometimes is pitted where red brass is not. Admiralty alloy is remarkably good for all cold waters, but very corrosive waters, if hot, will dezincify it.

The merit of tin coating is not clear-cut and is somewhat controversial. There is no question but that tin coating is the best remedy for staining in cold waters. In hot waters it is doubtful whether actual corrosion resistance is improved.

Much research is now being carried out on this general problem. Water supplies are being studied to discover the factors causing such important differences in behavior. Much has already been revealed as to the roles of salinity, alkalinity, hardness, oxygen content, carbon dioxide content, pH value, free acidity and temperature. Along with these studies, corrosion tests, both accelerated and in actual service, are being correlated with analysis.

Copper Water Tube

A relatively new departure in plumbing pipes is the copper water tube with relatively thinner walls. Standard sizes of threaded pipe have much heavier walls than necessary to resist working pressures, but the lack of suitable fittings and methods of joining thinner walled pipes delayed any improvements.

During the last few years two distinct types of tube fittings have been developed. First, there was the so-called compression or flared type fitting, wherein a flared or expanded end of the tube was tightly compressed between two threaded parts; for such use, soft temper copper tube in long lengths was ideal. A later development was fittings with sleeve ends into which the tube itself telescoped. The joint was then made tight by "sweating" with solder, by some such method as indicated by the cut on page 22. Straight lengths of hard temper copper tube, 20 ft. long, were found to work out best with these.

Copper water tube brought certain prob-

lems to the mill. The somewhat thinner wall and the use of flared ends on the soft tube necessitated almost perfect freedom from minor physical defects. This was met by various deoxidized or oxygen-free coppers of superior soundness. Long lengths of the soft tube in diameters up to 2 in. also required a change in mill procedure and equipment.

In developing copper water tube for sweat fittings a number of problems had to be overcome. First, in order to get a strong, tight joint, it was necessary that the clearance between tube and fitting be maintained very accurately. Specifications now admit of a variation in diameter of only ± 0.001 in. on the small sizes and not more than ± 0.002 in. on any size. This requires accurate drawing of tubes, only possible by using tungsten carbide dies.

Another difficulty early encountered was the creep of soldered joints at steam temperatures when made with ordinary 50-50 tin-lead solder, and as a result of considerable study, a number of improved solders have been developed. Probably the best for this purpose is composed of about 95% tin and 5% antimony; its creep resistance is so markedly improved that any danger from such a failure of even a rather poorly installed joint seems highly improbable. For any unit stress in the joint the tin-antimony solder stands up three to five times as long at steam temperature as 50-50 tin-lead solder would at room temperature.

Sweat Fittings are Easy to Make With Copper Pipe. Faying surfaces of pipe and sleeve are carefully cleaned with steel wool, a thin coating of non-corrosive flux applied, the fitting assembled and uniformly heated (by brushing with air-acetylene flame) slightly above melting point of solder. Remove flame and touch solder wire to joint, whereupon melted solder is quickly drawn in by capillary action

Flexibility an Advantage

The soft copper tube also found a natural application in underground lines on account of its ability to be readily bent around obstructions and to yield to settlement of ground, both of which are outstanding advantages. Its adoption has been very rapid throughout the country. This soft tube with flared fittings has also been widely used in re-piping of residences for its ability to be "threaded" through partitions.

Copper water tube seems destined to be very serviceable for plumbing lines handling the less corrosive waters. Hundreds of water supplies are sufficiently corrosive to cause trouble with ferrous pipes but not sufficiently corrosive to require the relatively more expensive red brass. Copper tube also has a large and proper field as a competitive material on low cost construction or temporary jobs.

Copper water tube with sweat fittings has already come into very wide use on heating lines; it is ideal for supply lines and drain lines for steam and hot water radiation. (A typical installation in a residence is shown above.) Its light weight and hence its low heat capacity, its smooth inside and consequent low frictional resistance, its freedom from corrosion products which would foul the line or clog delicate thermostatic valves make it ideal for such use. An additional advantage is that steam generated at the boiler travels to the radiators at the far end of the line much more rapidly than in screwed steel pipe. Another advantage of a thin wall is that a given nominal size has greater actual steam capacity than steel pipe.

On compressed air lines, especially brake lines on railway cars, copper water tube and sweat fittings have a tremendous advantage over previously used materials. Here the low first cost, the low frictional resistance, and the corrosion resistance are all highly important. The low friction loss makes for rapid action of brakes on a long train. Freedom from corro-

...pper Tube and Sweat Fittings in a Domestic Heating System

sion products to clog valve mechanisms is also a very considerable factor.

In refrigerator systems using the newer refrigerants such as "freon," it is extremely difficult to get tight lines. This refrigerant has escaped readily through joints absolutely tight to air or water. Exhaustive tests have shown that sweated joints in copper water tubes remain impervious to this gas under the most severe conditions.

Other applications where the desirable characteristics described above are of importance are in hydraulic lines, oil burner supply lines, oiling and greasing systems, air conditioning and vacuum lines.

Condenser Tubes

For many years admiralty alloy (70% copper, 29% zinc, 1% tin) was the generally accepted and almost exclusively used alloy for condenser tubes, and on the whole gave excellent satisfaction. In time the increased requirements due to design led to a demand for better alloys. Increased corrosion was also a very real factor, since water in our large harbors is now about the most corrosive medium encountered outside of strong acids or chemicals. Not only has it been found that dilute sea water is decidedly more corrosive than normal sea water, but harbors are generally much polluted by factory wastes and sewage discharges. Power plant designers and operators have also tended toward higher fluid velocities in the condensers and higher operating temperatures while forcing the equipment to capacity. All these factors mean increased severity of service and users have demanded and are now obtaining better materials.

One of the successful newer condenser alloys is aluminum bronze (which might more properly be called aluminum brass), composed of approximately 76% copper, 22% zinc, 2% aluminum. This offers superior resistance to a certain type of corrosion resulting from impingement of entrained air bubbles, on account of the unusual film-forming characteristics of the aluminum contained in the alloy. A very thin, tenacious and invisible, but highly resistant film, is rapidly formed. This film is extraordinarily resistant to breakdown; even when it is broken it has the property of self-healing not present in films on ordinary brass.

The cupro-nickels, composed usually of 80% copper and 20% nickel or 70% copper and 30% nickel with or without some zinc, have also gained rather wide acceptance for condenser use. As described by Robert Worthington in METAL PROGRESS last July, these alloys are totally different in their nature and behavior from the aluminum brasses above referred to, for they are intrinsically more noble, and owe their corrosion resistance to a low inherent tendency to go into solution in most waters. Cupro-nickel probably owes its superiority to its resistance to attack even if the surface film is penetrated by impinging air bubbles. It also seems to offer excellent resistance to so-called waterline attack and to oxygen concentration cells resulting from contact with foreign bodies.

One of the most recent developments has been copper-nickel-aluminum bronze. This alloy seems to combine the best properties of the aluminum brasses and of the cupro-nickels. The alloy favored at present is composed of approximately 92% copper, 4% nickel and 4% aluminum. By actual test it has been found to have extraordinary resistance to practically all types of corrosion and in a very wide variety of corrosive solutions, including normal and dilute

sea water. The nickel imparts marked improvement in inherent resistance, and the aluminum performs its above-described function of film formation.

With the above three general developments, and others still in the experimental stage, it seems that the increased requirements in this field will be adequately met.

Refrigerator Tubes

Artificial refrigeration has developed a need for copper tubes of rather unusual characteristics. In the first place, very long coils up to 100 ft. or more have been required, finished by plug drawing a pierced billet. Apart from all other considerations, this has required considerable engineering skill. Tubes of desired characteristics are now obtainable in any reasonable length.

Apart from the question of length, refrigerator tubes require rather unusual quality as determined by freedom from scale, oxide, physical defects, adherent dirt and moisture. In short, a tube is demanded which is chemically clean and dry. This requirement has taxed the ingenuity of the engineer and research worker in the copper and brass industry.

Manufacturers first resorted to the practice of cleaning the tubes after the final anneals — as by bright dipping followed by rinsing and drying, or sand blasting the interior, or annealing when filled with gas. The first two methods were but temporary, as the costs and difficulty of handling the long tubes were too great. For a time the best accepted practice after the final draw was to go through a sequence of operations involving cleaning, drying, gas filling, sealing of ends and annealing. While an excellent product was obtained, the operation was very slow and somewhat expensive. Extreme care had to be exercised all the way through to insure tubes of consistently high quality.

A rather revolutionary bright annealing process for such tubes has now been developed. The furnace is such a one as shown in the photograph on the front cover of this magazine. It is of the conveyor type, electrically heated, with a special gas atmosphere in a long muffle. The coiled tubes are first flushed out with this gas, laid on the conveyor, carried up through the heating zone, and then through a long cooling zone before leaving the furnace, when they are ready for immediate boxing for shipment. This avoids the necessity of sealing the ends of a gas-filled tube, which is a tremendous advantage. (Copper can readily be bright annealed in a steam atmosphere, but if steam were used, it would get into the tube and condense on cooling, and fail to meet the requirement for a dry tube. Furthermore, the condensate would stain both the inside and outside.)

No Sulphur Permitted

It would seem offhand that the use of cracked natural or city gas, butane, or propane atmosphere would be simple and offer no difficulty. However, hot copper picks up sulphur with extreme rapidity, and this results in a very unsightly stain. In natural gas and most butane or propane there is considerable sulphur, but this is present in inorganic compounds and is fairly readily removed by the usual scrubbing process. With such cracked and scrubbed gas atmospheres a beautiful product is produced which can be taken from the furnace and put directly into the packing case for shipment.

City gas presents an additional difficulty. This gas contains not only considerable inorganic sulphur, but appreciable quantities of organic sulphur not removed by the ordinary scrubbing process. Due to a very fine piece of research work, a process for converting the organic compounds to inorganic sulphur is being commercially developed. This has been difficult on account of the exceedingly small quantity of sulphur that will tarnish copper at the temperatures involved. Whereas one grain of sulphur per 100 cu.ft. of gas is ordinarily considered a low concentration, it is found necessary for this work to reduce sulphur to something like 0.003 grain per 100 cu.ft., which requires meticulously careful handling and manipulation.

As a result of all these items copper tube is now available for refrigerator or other uses, bright annealed, clean, and dry, which from the standpoint of quality is probably one of the most perfect materials ever produced in our industry.

By A. E. White
Director
and Richard Schneidewind
Research Engineer
Dept. of Engineering Research
University of Michigan

Malleable cast iron annealed in a short cycle

MALLEABLE iron is an important member in the group of ferrous metallurgical products. It is widely used in agricultural implements, automobiles, engine parts, hardware and building equipment, pipe fittings, and railroad equipment. There are about 150 plants in the United States engaged in its manufacture with an annual capacity of 1,350,000 tons.

The average physical properties of American irons, figured from some 20,000 tests from 117 investigators, are reported in a Symposium in 1931 to the American Foundrymen's Association:

Tensile strength	54,000 lb. per sq.in.
Yield point	36,000 lb. per sq.in.
Elongation in 2 in.	15% minimum; 18% average
Brinell hardness	115
Izod impact	9.3 ft-lb.
Endurance limit	25,000 lb. per sq.in.

Modification in composition and heat treatment may raise the tensile strength close to 70,000 lb. per sq.in. with elongations from 18 to 20%. The hard white cast irons which are usually malleableized in this country are iron-carbon-silicon alloys containing usually from 2.0 to 2.5% carbon and from 0.9 to 1.2% silicon. Because of the added fluidity many plants aim at as high a carbon content as possible for a given silicon without obtaining primary graphite in the metal as cast. However, many investigators have been advocating lower carbon contents because they result in better physical properties. Although casting difficulties are greater, some progressive foundries have been successful in making such low carbon, high silicon irons — silicon has been as high as 1.9% and carbon as low as 1.5%.

The American Society for Testing Materials recognizes two grades of malleable iron in its specification A 47 — 33. The specification for minimum requirements reads:

	Grade 32510	Grade 35018
Tensile strength	50,000 lb.per sq.in.	53,000 lb.per sq.in.
Yield point	32,000 lb.per sq.in.	35,000 lb.per sq.in.
Elongation	10%	18%

Grade 35018 represents a very considerable improvement in quality which has taken place during recent years. For instance, the A.S.T.M. specification in the year 1919 reads: Tensile strength, 45,000 lb. per sq.in. minimum; elongation, 7.5% in 2 in. minimum.

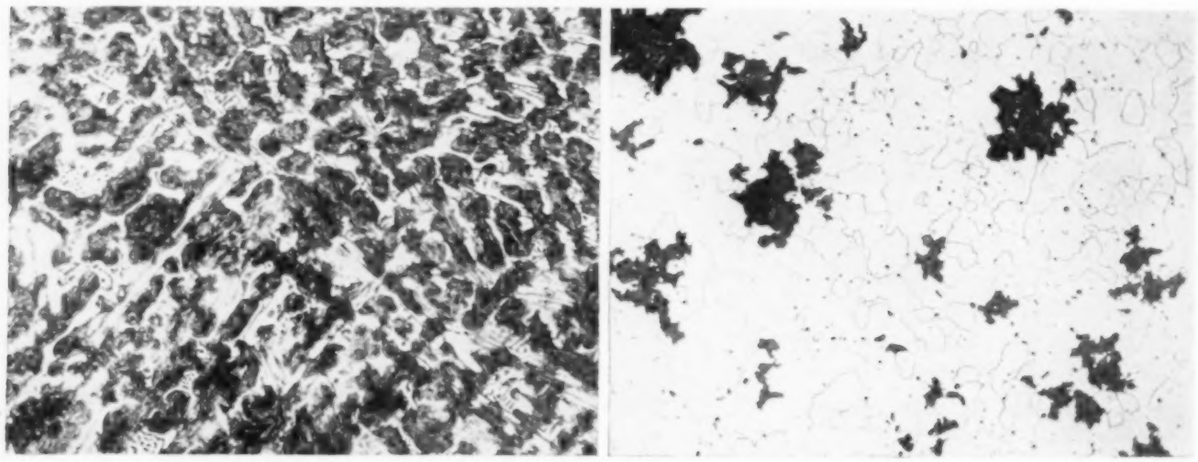
Short cycle malleable may be produced by modifying one or more of the three processes involved in the usual foundry procedure:

1. Melting — A charge of pig iron and scrap with sometimes small additions of steel is melted down in an air furnace or in a cu-

pola. Sometimes the metal is poured directly from the cupola, forming a hard, brittle, white iron which is subsequently malleableized, but usually cupola iron is refined and superheated in an air furnace or an electric furnace.

2. Casting — The molten iron is transferred by ladle into sand molds. Only a small amount of iron is cast in metal molds.

3. Annealing — After the sprues and fins have been removed, the hard castings are cleaned, then placed in pots and annealed to form soft, malleable, machinable castings. Annealing furnaces may be heated with oil, powdered coal, gas, or electricity. The first two are generally used because of lower cost.



Average Iron, Before and After Annealing. Composition 2.4% carbon, 1.03% silicon. Etched with 3% nital and magnified 100 diameters

The metallurgical change accomplished by annealing transforms the white iron (composed of free carbides and pearlite) into a structure composed of graphite and ferrite or, more strictly speaking, graphite and silico-ferrite. Accompanying photomicrographs represent the usual conditions.

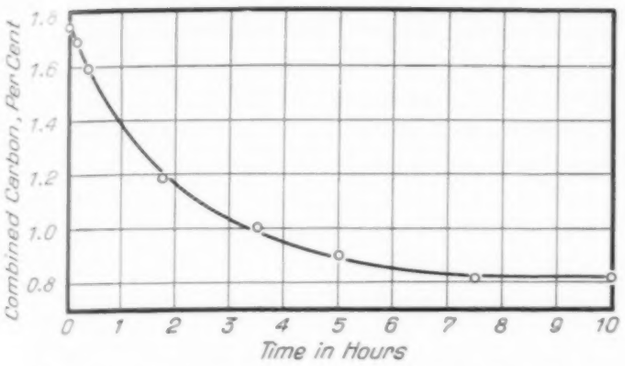
The time required for annealing this "standard" malleable iron varies from five to seven days. The annual annealing cost in the United States in normal times is about $18,750,000. Other important considerations are the delay in the production of hurry-up orders and the cost of adequate furnace equipment.

Comparatively little work was done on shortening the time of malleableizing until after 1920. Since then, many articles and patents have appeared which claim to decrease the time by various means. Many involve a change in the composition, and some few of them are being used in commercial applications. Other methods claim to save time principally by maintaining certain significant annealing temperatures and carefully controlling the cooling rates. The trend is toward higher annealing temperatures. Well-designed furnaces and accurate control methods are, at any rate, of greatest importance.

The ultimate goal of the research which has been carried on for three years in the Department of Engineering Research of the University of Michigan under the sponsorship of the Committee on Industrial Gas Research of the American Gas Association, was to throw new light on the factors underlying the mechanism of graphitization in order to point the way toward a shorter cycle for the production of malleable iron in industry. A brief statement of our present ideas may be useful.

Mechanism of Graphitization

White iron, as cast, consists of the decomposition product of austenite — that is to say, either pearlite or sorbite — together with a constituent generally referred to as "massive cementite" but what is really a eutectic of iron silicide (FeSi) and iron carbide (Fe_3C). Iron silicide has a transformation point at which FeSi changes into Fe_2Si_2, so that under different manufacturing conditions and rates of cooling



Curve Showing That the Amount of Combined Carbon in White Iron Is Reduced to a Fixed Limit After Long Heating at a Steady Temperature — in This Case 1700° F.

(due to the size and shape of the mold) it can be expected that varying proportions of Fe_3Si_2 are also present.

It is believed that the formation of graphite nuclei at the soaking temperature is a result of two simultaneous reactions:

$$Fe_3C \rightarrow 3\,Fe + C$$
$$2\,FeSi + Fe \rightarrow Fe_3Si_2$$

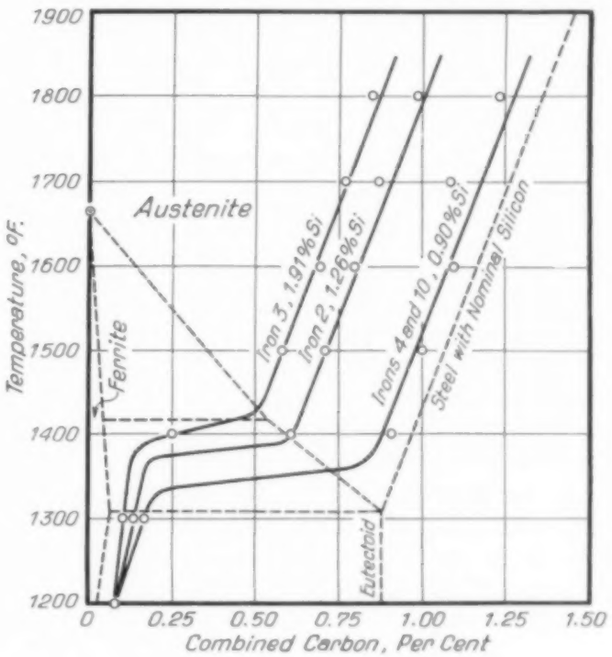
No detailed discussion of this theory will be given here to indicate how carbon is transported through the metal to accumulate in certain regions, but it may be said that it does satisfactorily explain many observations.

At the soaking temperature the formation of nuclei of graphitization starts immediately. It is our belief that these nuclei are not inherent in a given iron, as is often stated, but that the nucleus-forming capacity (which can be set in motion by the heat energy supplied in annealing) is inherent. If the actual nuclei were pre-existent, two specimens of the same iron annealed at different temperatures would have the same number of temper carbon particles per unit volume. Experiments have shown that this is not the case.

The problem of graphitization was attacked by us from two angles, namely, the solubility of carbon in gamma or alpha iron as it varies with temperature, and the rate of graphitization. Factors affecting these two phases of the problem were then investigated.

When a white iron is soaked at a temperature above the critical, the amount of combined carbon approaches some equilibrium point corresponding to the solubility of carbon in gamma iron at that temperature. That is to say, when

Solubility Relationship Between Carbon and Iron as It Is Affected by Temperature and Silicon. For instance, if white iron No. 3 containing 1.9% silicon is heated to 1700° F., all the carbides decompose fairly rapidly into iron and graphitic carbon except that 0.75% of carbon remains in solid solution in the austenite. With slow cooling even this decomposes, the amount of carbon held in undecomposed iron carbide at any temperature being indicated by the curve



the metal has been heated steadily for a sufficient time, all the massive carbides have been decomposed and all the carbon above that required to saturate the austenite (supposedly as carbon in solution in gamma iron) exists as free carbon or "temper carbon." Additional heating at this temperature produces no further change; this can be seen from the curve in the first diagram.

At a different annealing temperature the same process takes place except that the carbon distribution comes to equilibrium at some other proportion. Equilibrium can also be approached by heating a fully annealed iron — that is, one containing no free carbide — of the same composition to the same temperature.

Likewise, an equilibrium can be reached by heating a white iron to a temperature *below* the critical; it is possible to produce fully annealed malleable iron entirely below the A_1 temperature. Since such an operation may take from 500 to over 1000 hr., the solubility values are best obtained by heating to equi-

librium above the critical and then lowering the temperature to the desired point below the critical. Commercial malleable iron is therefore made in two stages. The iron is heated above the critical until the massive carbides are decomposed and graphite nuclei are formed; it is then cooled slowly to some temperature below the critical in order to graphitize the remaining carbide, which was in solution in the austenite at the higher temperature.

It can be seen from the second chart on page 27 that silicon appreciably changes the solubility. The full lines are simply the lower ends of the "stable" iron-carbon equilibrium diagrams, and could, of course, have been derived from a study of the iron-carbon-silicon system. The important fact for our present consideration is that the higher the silicon, the greater is the amount of carbon graphitized above the critical, which process is much faster than the corresponding one below the critical, and the less is the amount of carbon remaining in solution which must be later graphitized slowly at the lower temperature.

Other elements will similarly modify the solubility relationship. Nickel, for example, alters it favorably while chromium and molybdenum make graphitization more difficult.

Effect of Foundry Variables

The curve plotted on the first figure on page 27 is a logarithmic curve, which indicates that the graphitizing reaction at any temperature follows the law of mass action. Speed of graphitization may therefore be predicted to increase logarithmically as the temperature of annealing rises. Practically it is also found that a fluctuating soaking temperature graphitizes more rapidly than a constant temperature.

Too high an initial temperature must be avoided because of the increased danger of scaling and warping and because the physical properties are liable to suffer through an unfavorable distribution, size, and shape of the temper carbon.

The atmosphere in the annealing furnace has but little or no direct effect on the rate of graphitization. Its indirect effect is considerable, however, since by the use of a proper reducing atmosphere, oxidation can be kept at a minimum, the packing material may be eliminated, and the tendency for the formation of "pearlite rings" is lessened.

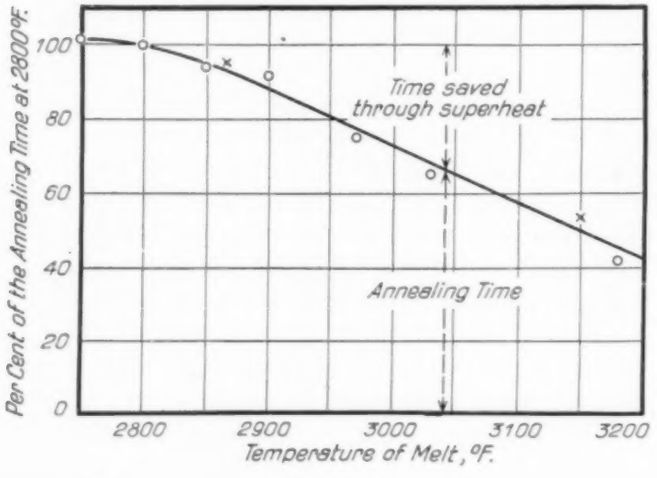
Among foundry conditions which affect the rate of graphitization, one can enumerate (*a*) the rate of cooling of the molten iron, (*b*) the superheat employed, and (*c*) the composition and impurities in the iron. The more rapidly the metal is solidified and cooled, the more rapid will be the subsequent graphitization. For this reason, permanent mold castings will graphitize with extreme rapidity. Since the rate of cooling is more or less standard, because sand molds are used in nearly all foundries, the only factor which can change the rate of cooling is the temperature at the ladle spout.

It has been found that if a metal is heated to a high temperature during melting, it will graphitize in shorter time than metal of the same composition melted at a lower temperature. This condition holds true, even though the casting temperature is kept constant. The curve alongside shows this relationship clearly.

In the matter of composition, silicon is the most effective factor in accelerating the rate of graphitization. Other things, such as carbon content, pouring temperature, and superheat, being equal, increasing silicon content decreases the time necessary for graphitization in a logarithmic proportion.

Total carbon content is theoretically but a minor factor. In practice, however, it may be important because with higher carbon the fluidity of the melt is better, so that there may be a tendency to melt high carbon iron at

Iron Graphitizes More Quickly the Hotter It Is Melted

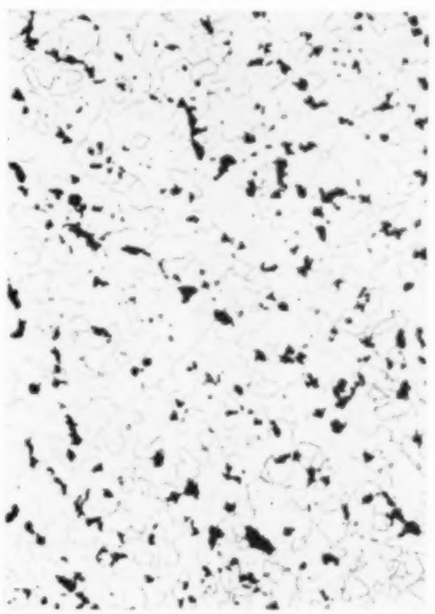


lower temperature and to pour it at a lower temperature, and thus fail to get the accelerating effect of a proper superheat.

In quantities met commercially, sulphur and manganese are not vital factors if a proper relationship between the two is maintained.

Too high a phosphorus content is detrimental since it promotes segregation. Some foundries have reported difficulty in annealing the resultant white iron when phosphorus is present in the pig iron in the form of steadite. In high silicon irons, the phosphorus content must not be permitted to rise too high.

High silicon malleable containing more than 0.18% of phosphorus will satisfactorily pass a Walker wedge test, but it is often brittle in zero weather.



Malleable Iron Completely Graphitized in 6 Hr. Analysis 1.4% carbon, 1.7% silicon. Superheated at 3150° F. in a Detroit electric rocking furnace

Fast Graphitization

Study of a large number of irons has shown that all factors which decrease the annealing time do so by altering the size, distribution, and number of the particles of temper carbon. It is obvious that the graphitizing action is largely a diffusion process, the combined carbon having to diffuse to and deposit upon a graphite particle. If the graphite particles are close together, the distance any atom has to diffuse is decreased and in this manner, graphitization is speeded up. A short cycle malleable iron, then, should be one which forms graphite nuclei rapidly and in large numbers.

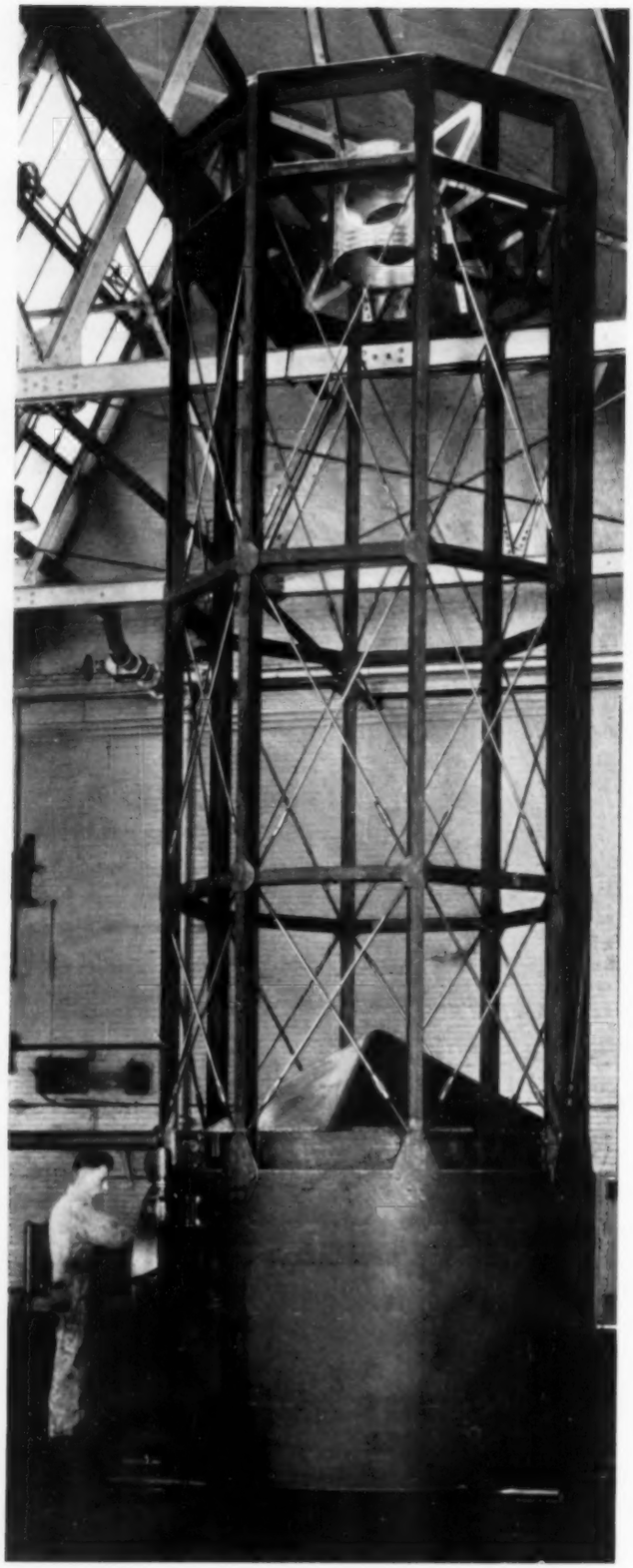
An iron containing 1.5% carbon and 1.7% silicon has been graphitized in a total time of 6 hr. Its microstructure at 100 diameters is illustrated on this page. This represents an extreme case, but is indicative of what can be done by increasing the silicon and a high degree of superheat. An iron of the same composition with less superheat required 15 to 18 hr. for complete graphitization. The physical properties were in the neighborhood of 65,000 lb. per sq.in. tensile strength, 45,000 lb. yield point, and 15 to 18% elongation.

Various practical considerations are encountered in the manufacture of short cycle iron. First, as the silicon content is increased, the carbon must be decreased to avoid the formation of primary graphite. The lower carbon decreases the fluidity of the melt so that there is greater danger of shrinks and blow-holes. This difficulty is a serious one, yet one of the principal automobile manufacturers and some of his suppliers are casting large tonnages of iron containing about 1.9% carbon and 1.65 to 1.9% silicon.

If a considerable degree of superheat is desired, it is necessary to duplex the iron. This entails additional time, and the expense of operating an electric furnace with its electrodes and lining may be considerable. Large tonnages of such iron are being produced yearly, however.

The type of annealing furnace is also very instrumental in cutting down the time of annealing. The most successful furnace so far is the tunnel type, and much iron containing 2.75% carbon and 1.15% silicon is being produced in it in 51 hr. or less. Batch-type furnaces would undoubtedly take 90 to 110 hr. to accomplish the same end.

High silicon, low carbon irons are stronger than the conventional malleable irons and they open a new market. Another interesting new development lies in the field of partially malleableized or heat treated malleable irons. These consist metallographically of temper carbon in a matrix of ferrite and spheroidized carbides or pearlite. The strength of such alloys sometimes reaches 90,000 lb. per sq.in., with elongation of 3 to 4%—See Mr. Bornstein's article in METAL PROGRESS last August.



Welded Tube for 69-In. Telescope, Made by Warner & Swasey for Ohio Wesleyan University. Procedure control is responsible for a light, rigid, inexpensive structure, entirely suitable for the purpose intended. Photograph courtesy Lincoln Electric Co.

PROCEDURE control in welding involves finding the right way to do a job, then doing it that way every time.

The principles of procedure control are applicable to any manufacturing or construction operation where a predetermined result is required. These principles are not new. Only the term originated in the welding industry, but it is sufficiently inclusive to be properly used in many other places.

In the construction of welded assemblies it is necessary that effective procedure control be established. This control should be comprehensive, extending to all operations from the original design to the final testing of the piece preparatory to being put into service. If one or more workmen involved in any of the operations is free to use his own judgment in anything but strictly routine matters, a chance for error has been introduced. Such cases are, of course, unavoidable in many repair operations and in certain engineering construction, and for such work only the most mature and conscientious workmen are suitable. But it is borne out by experience in mass production that as the number of places at which individual judgment can be employed increases, the number of failures increases, and the financial penalty is usually so high that complete procedure control becomes a necessity.

Acceptance tests are widely used in all industries. It might be thought that the use of non-destructive testing methods, such as static loading or X-ray examination or both, would eliminate the necessity for procedure control. On the contrary, they accentuate it. Such tests, when first introduced, have always shown an astonishing lack of uniformity in the finished product — and the product of the welding art is no exception to that statement. Accelerated life tests disclose still more variations in the product not discovered by static loading or X-ray examination. The net result of relying on acceptance tests and neglecting adequate procedure control is that a considerable amount of the work must be rejected or done over again.

by Robert E. Kinkead
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Procedure control in welding

Elimination of individual judgment or choice of materials or methods from controlled welding operations, insofar as the operating forces are concerned, is a very effective method of placing responsibility where it belongs. When trouble is encountered an investigation can start from the point at which it may be said that either (*a*) the methods and material specifications were not carried out, or (*b*) the specifications were not correct. In either case, the trouble can be found immediately and corrected. But where individuals all along the line can do about as they please, it is difficult to hunt down the cause of trouble or to insure that it will not happen again.

In the accumulation of experience now available with welding operations and welded structures, the great majority of troubles may be traced to the fact that no precise methods or material specifications were given by the responsible engineers and managers to the operating forces. One case with which the writer is familiar, involving the payment of about $50,000 damages, was the result of the operating forces talking the engineers out of a perfectly correct specification. Another case involving heavy damages to a governmental bureau was due to the circumstance that a manufacturer of welding machines wrote the specifications in such a way as to require his equipment and left the matter of materials, and practically everything else to the choice of the operators. In still another case involving heavy damages, the entire operation was left entirely to the judgment of the operators who were coached by the manufacturer of the welding machines.

In all of these cases, there was a lack of responsible engineering by some party to a major transaction. There are, of course, some cases of trouble where the specifications were adequate from the technical point of view but proper inspection was lacking, so that there was no conclusive evidence that the specifications were actually followed.

In the absence of specifications definitely recorded for methods and materials — that is to say, procedure control — any trouble results in confusion. Various individuals all along the line start changing methods and materials. Perhaps a satisfactory result is then obtained but no one knows for certain why it was obtained nor how to produce it every time.

In welding as in other technical operations, it is not sufficient to obtain the correct result 98 times out of 100. One or two service failures may result in losses which wipe out working capital and destroy good will. It is also true that there is no logical basis for estimating costs unless the service results of the welded structure may be accurately predicted. Material, labor, and overhead burden are primary cost elements, but unless service behavior can be predicted the *total* cost is doubtful.

The experience of an excavator manufacturer illustrates the point. Nineteen steel castings weighing 35,000 lb. each were bought for a certain model. The price was less than the estimate on welded steel construction in-

volving an assembly of hot rolled steel parts. Within ten months, 16 of the castings had failed due to hidden defects. The foundry replaced the rough castings but the manufacturer had to machine them at his own expense, dismantle the equipment in the field and put it back in operating condition. The manufacturer obviously did not find out the real cost of those castings for at least 18 months! He then changed over to welded assemblies of hot rolled steel, recognizing that even though the welds might be slightly defective, he could put them where they would carry the least load.

Now returning to the specific problem of procedure control, it is quite as logical to have precise and recorded instructions covering materials and methods involved in welding operations as it is, for instance, in heat treating practice. But, in the case of welding operations, a much larger number of variables must be held within predetermined limits. Such factors as sketch means simply that the algebraic sum of all tolerances must still be within proper limits to produce a satisfactory result.

Any manufacturer who enters fields in which he has had no previous experience should not feel that an adequate procedure control would be too expensive. How else can he be protected? A calm appraisal of the experience of the last five years, during which a large expansion in use of welding has occurred, indicates that welding is entirely too expensive to use *without* effective procedure control. Without it, no one will know what a welding will cost him until a year or two has elapsed. It has been the usual experience that the final cost is more than the combination of material, labor and overhead burden — in some cases, to an amount fatal financially.

This discussion about management of welding operations may appear somewhat academic without some recognition of conditions as they

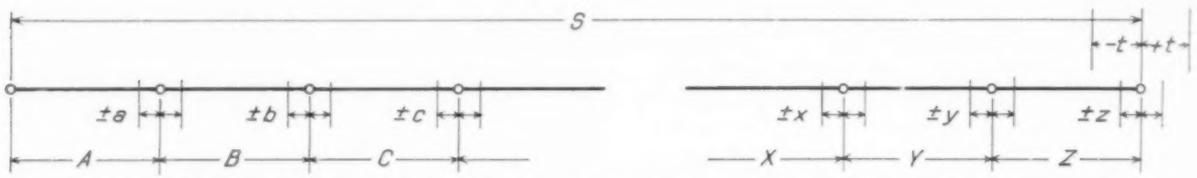

Diagram Indicating Tolerances of Unit Operations A,B. . . . .Y,Z and Allowable Tolerance of Completed Job S. S equals A plus B plus C. . . . .but the tolerances a, b, c, d, must some of them be plus and some minus so that the final result is within the acceptance limits of ± t

the following, in uncontrolled variation, may throw the final result clear out of prediction:

1. Chemical analysis of the steel welded.
2. Behavior of the welding rod.
3. Size and shape of the weld kerf.
4. Amount of heat and speed of travel.
5. Shape of weld beads.
6. Ambient temperature when finished.
7. Method of stress relieving.

There are many variables other than those listed above which must also be brought under control by the management and supervisors, either in a well-established routine or by careful instruction and specification for individual cases. Limits of variation of all of the factors involved must be established if a predictable result is to be obtained. Due consideration must be given to the circumstance that two or more factors may be varying at the same time, and the result must be predictable in spite of such combined variation. The illustrative actually exist in industry today, together with some suggestions as to what can be done about it. The installation and operation of a procedure control system of some kind is not, in itself, a considerable item of expense. It takes time and trouble to get an organization which has been used to doing things according to each individual's own judgment changed over to performing operations by predetermined schedule and specification, but the incentive is that everyone who has made any money out of welding has controlled the operations in this way.

The above statement implies that a considerable body of information on good welding practices is held by many organizations and engineers scattered throughout the United States. Too much credit for this state of affairs cannot be given to the activities and investigations of the progressive makers of welding equipment, gases, machinery and sup-

Procedure Control Is a Prime Essential in the Manufacture of Reliable Equipment by General Electric Co., One of the Leading Proponents of the Welding Method. View shows a row of domestic furnaces (oil-burning) in front of some large transformer tanks — all fabricated by welding

plies, and to the engineering societies which have broadcast the information as discovered.

Procedure control may be established by using the experience of any one of a number of professional engineers specializing in welding. Some manufacturers have based their practice on the data easily available and developed their own procedure control with a minimum of trial and error and thus obtained conspicuously successful results. Where a concern has plenty of working capital, some partly idle employees who would be paid full-time anyway, and ample time to reach a satisfactory degree of control, the latter plan works well. On the other hand, some fabricators are now taking long and desperate chances on welding operations in the hope of getting one good contract that will turn out to be profitable. Under these circumstances advice is sought from visiting salesmen, or anyone who has ever had any contact with the welding industry. Such advice, even when it is good, has to do with specific questions and not with the fundamental problem which the management faces.

Procedure control in welding has its analogy in every line in which successful and profitable manufacturing is carried out. An automobile rolls off an assembly line with a tank full of gasoline and it will run; *that* is the result of procedure control. Food products, tobacco, radio equipment, are manufactured in millions of units — all alike, all to predetermined specifications (procedure control). Telephone apparatus is manufactured with a degree of precision almost inconceivable in other lines of manufacture. A slight error in the result, since the parts are manufactured by the million, would run the cost to staggering figures. Procedure control, in the fullest meaning of the term, protects the capital in the telephone business from such losses.

Procedure control is the foundation of modern manufacturing. Among those who use welding, the most successful, as shown by experience, are the manufacturers who have the most precise control over their results. It is difficult to escape the conclusion that safety of the working capital lies in that direction.

From an unpublished paper read before the Pittsburgh Section, Society of Automotive Engineers

by Karl Pfeiffer
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New developments in valve springs for gas engines

VALVE springs are not simply the product of a designer's calculation and a metallurgist's recommendations, but are evolved by months of development work and tests in experimental laboratories, and are based on a very large body of experience acquired by leading spring makers and spring users. When top engine speed was about 2800 r.p.m., it was comparatively easy to obtain satisfactory springs. Increasing engine speeds, year by year, added some serious complications, and today valve springs are considered as important for the correct operation of the engine as pistons, connecting rods, and crankshafts.

The duty of a valve spring is to force the valve and push rod or tappet to follow the cam at all speeds. To do this the spring must overcome suction, pressure and inertia. It may be accomplished by many different coiled springs having various dimensions and made of almost any stiff material. It is the experimental engineer's job to find the best possible compromise, which is a spring that will last as long as any other part of the car and will be commercially satisfactory from the standpoint of design and material. It is this phase I wish to discuss.

Although there are numerous possibilities when one comes to selecting the diameter and length of the spring, it has been found through experience that the ratio of the length, at valve closed position, to the mean diameter should be approximately two to one. The best proportion of mean coil diameter is between 5.5 and 7 times the wire diameter. If this ratio is too small, there is danger of overstressing the metal on the inside diameter, thereby causing premature failure.

Spring design is not only determined by the load and stress requirements, but is also influenced by surge, which multiplies the number of stress cycles through which the spring must go, thereby reducing its natural life. As a general rule, springs with a low rate vibrate with greater amplitude than springs of higher rates. Therefore, under dynamic conditions, the real stress in a low rate spring may be greater than the real stress in a high rate spring. Since the maximum stress range, from valve closed to valve open, is directly related to the rate of the spring, the engineer is forced to compromise between high stress range and surge. Since high stress is considered the lesser of the two evils, we find many valve springs intentionally designed to work above a unit stress that would have been considered safe a few years ago.

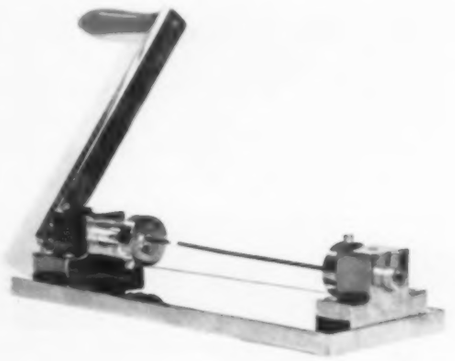
Development of successful valve springs for fast engines has depended upon the discovery of a suitable material for the calculated stress requirements. About ten years ago, when the average valve gear speed was around 1300 to

1400 r.p.m., the metal most commonly used was a hard drawn or patented wire of plain carbon steel. This wire obtained its physical properties mainly from cold work in the drawing die and was relatively cheap.

As the valve gear speeds rose above 1500 r.p.m., it was found that the proper selection of material became of the first importance. Patented or hard drawn spring wires were replaced by oil tempered, high carbon wire of American manufacture. Because of non-uniformity of structure and physical properties and the presence of mechanical defects, this wire did not eliminate spring failures and it was quickly discarded.

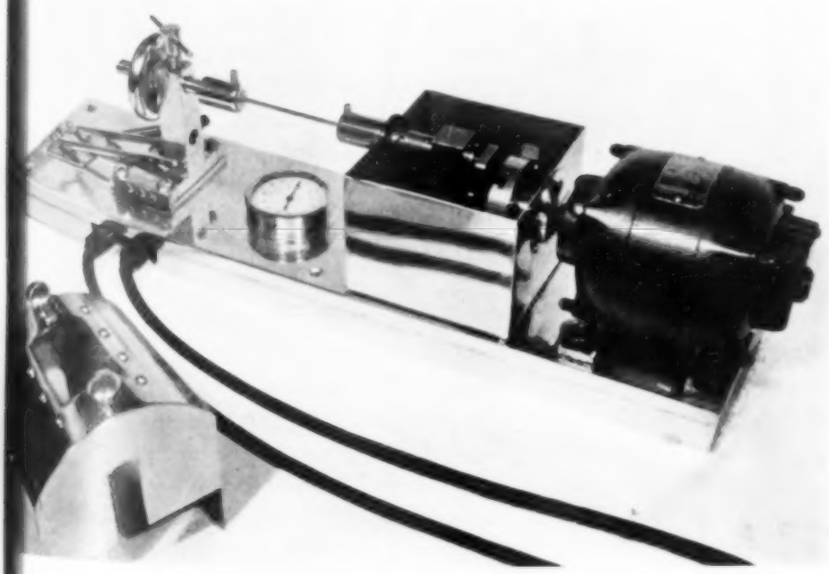
Alloy steel had solved many problems on other parts of the automobile and the metallurgist naturally turned to an alloy wire. Chrome-vanadium wire was then adopted by all manufacturers building engines with top speeds of 3400 r.p.m. and over. It conformed to S.A.E. 6150 and was made in the electric furnace. However, the results were discouraging because spasmodic epidemics of failures still occurred, which were always traced directly to defects in the wire. While this material gave excellent results when the wire was sound, it seemed to have a tendency toward seams and surface defects which at times proved disastrous. It was not unusual for valve springs, made from chrome-vanadium wire, to break during the run-in period of engines in production, or during the block test. Such breakages, occurring after a few hours of service in the engine, were invariably traced to surface imperfections.

An interesting experience may be mentioned at this point. A spring manufacturer was asked for a set for a racing engine, coiled from the best material he could get. He made up twice as many springs as needed from chrome-vanadium wire and deep-etched alternate springs as they came off the coiling machine to make sure that the wire was free from surface defects. The unetched springs were installed and operated successfully throughout a complete race.

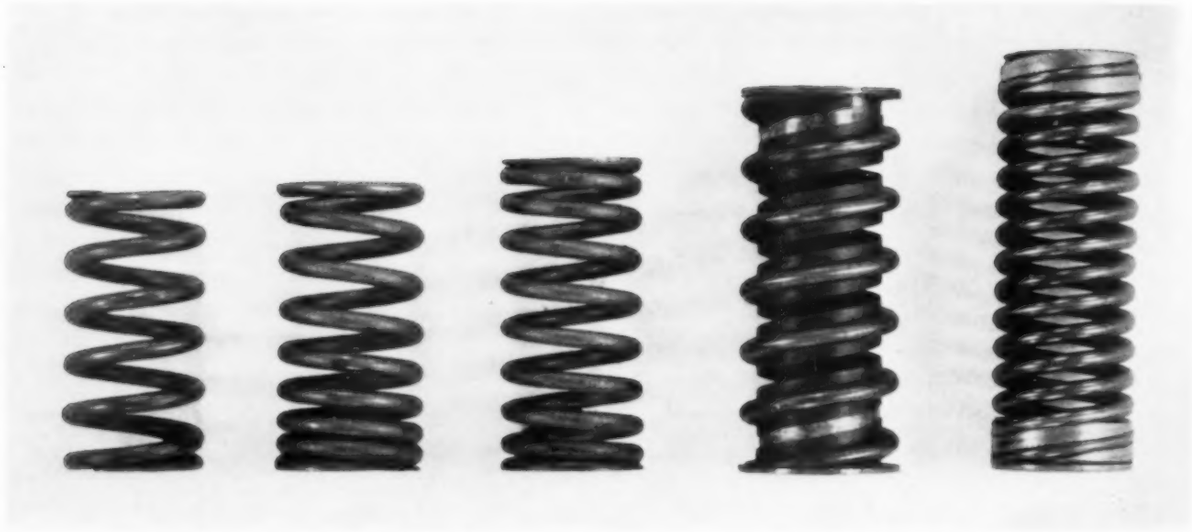


Simple Device for Twisting Sample of Valve Spring Wire to Failure

Many more or less satisfactory attempts were made to obtain a better surface. The final result, however, was that many spring companies have discarded chrome-vanadium wire for a material that gave consistent results, and this was the carbon wire which they felt had not been given the proper chance to prove its intrinsic merit. With the physical properties of the alloy wire as a standard, a carbon wire was finally developed in Sweden which was a good match for it. This steel has



Fatigue Testing Machine for Wire. Angle of twist may be varied by the coupling between motor and test piece



Modern Springs Designed to Avoid Surge or Shimmy. From left to right: (a) Uniform pitch spring with high rate; (b) Increased pitch from end to end; (c) Variable pitch from ends to center; (d) Spring made from "fin-wire"; (e) Dual or interlaced springs of high rate

been consistently free from injurious mechanical imperfections and spring failures have been almost negligible.

When carbon steel was adopted by the Chrysler organization in 1928, a comprehensive series of acceptance tests was specified for the wire as received from abroad. Samples were taken from each end of every coil of wire to test both in tension and torsion. The slow torsion test is quite simple, and is done in the device shown in the first illustration; pieces of wire were slowly twisted to failure, to determine torsional ductility and type of fracture. The other machine, shown on page 35, was developed to test a piece of wire for its torsional fatigue resistance by holding one end stationary and twisting the other end at high speed through a predetermined angle until it broke. In addition, these samples were used to determine hardness, cleanliness, density, and type of structure, and finally they were deep-etched to study their surface condition. Because of the structural uniformity of the wire, shown by numberless such tests, only the deep etch test is now made on each bundle.

Despite the success of this imported material, experimental engineers are not satisfied with the present conditions. All indications are that future engines will run 4500 and 5000 r.p.m. The spring material that will fulfill these requirements will have the same ductility as the present-day wire but much higher fatigue resistance. This is the problem our steel men have to solve in the near future.

Surge or "Shimmy"

A valve spring may not be a well-engineered spring even though designed according to the best available spring formulas and made from the most suitable wire. It may be responsible for faulty engine operation, noise, and failure, all of which may be traced to surge.

Surge is a vibration of the wire between its two ends set up by the impact of valve closure. A more scientific definition was given by W. T. Donkin and H. H. Clark in a paper read before the Society of Automotive Engineers in 1927: "Valve spring surge is a product of a resonant condition between the rate of the forced vibration due to the camshaft and the natural frequency of the spring."

Service complaints will result if a spring that has one or more bad surge periods is installed in an engine. Surge vibrations may even cause a singing noise audible to the driver. It is not intended to advance more information on surge nor to submit additional fomulas for calculating vibrational frequencies, but rather to demonstrate how the experimental engineer arrives at a commercially satisfactory spring.

One way of eliminating surge is to design

a spring of uniform pitch and very high rate, such as the one at the left of the line-up illustrated, with sufficiently high natural frequency to be practically free from surge over the entire operating range. Another attempt along this same line is the one shown at the right end of the line, made of two identical springs of large pitch, held coaxially and equally spaced by end washers, the coils being located in the same relative position as the threads on a double lead screw. This spring, which has a high rate and a very high natural frequency, has been used satisfactorily by one of the large manufacturers, but high stresses are involved and it is only an occasional solution of the problem.

The most frequently used method of reducing the effect of surge is to coil the spring with the pitch increasing from one end toward the other, or from both ends toward the center, as shown by the second and third springs in the line-up. The rate and frequency are varied while the valve is lifting, and it is therefore difficult for the spring to become resonant. Attention must be given to quietness, as the closely wound end-coils often clash. Another very important point is to avoid excessive bending stresses on the end coils which progressively contact with each other during the working period.

Several well-known automobile engines are now using uniform pitch, low rate springs in combination with various types of friction dampeners. These springs have poor dynamic characteristics when operated alone, but are commercially satisfactory in respect to surge when the friction dampeners are new. The disadvantages of spring dampeners are complication, cost and possibility of abrading the wire.

In order to demonstrate how far experimental engineers have gone in search for a means to eliminate valve spring surge, the following two extremes may be mentioned: Since it is known that the mass of the spring had to be as light as possible for a given amount of torsional rigidity of the wire, some were made from hollow wire. Surge characteristics were excellent; the life, however, was very low. Examination showed that failures were due to the eccentricity of the inside hole, which was fluted or star-shaped instead of being round and concentric with the outside surface.

Another test was conducted with springs made from "fin-wire," as shown in the next to last spring in the row. This wire was not drawn from a bar but had to be rolled with two diametrically opposite thin fins. The purpose of these two thin fins located in the vertical position was to give the spring high bending resistance without changing the torsional rigidity. Difficulties in the manufacture and coiling of this wire section prohibited the commercial use of fin-wire valve springs.

It is not very difficult to eliminate valve spring surge on stationary and marine engines, which run at an almost constant speed, for the valve spring may be designed to be free of bad periods at or about the particular speed at which the motor operates. It is comparatively easy to shift the period lower or higher in the speed range. The same statement is true of valve springs used for racing and aircraft.

For motor car engines the final dimensions of the spring, especially coiling pitch, are not arrived at by calculation, but by trial and error in actual tests. Most spring manufacturers and automobile plants possess different types of valve gear set-ups on which sample springs can easily be installed and observed with the naked eye, or by means of stroboscopes. One such is illustrated on page 38. Stroboscopes are instruments for reducing fast speeds to slow motion, and have long played an important part in the development of dynamic springs. They enable the observer to estimate the approximate frequency and amplitude of spring vibrations and to determine the speed at which they occur. Recording instruments have also been developed to eliminate the human element from the observations.

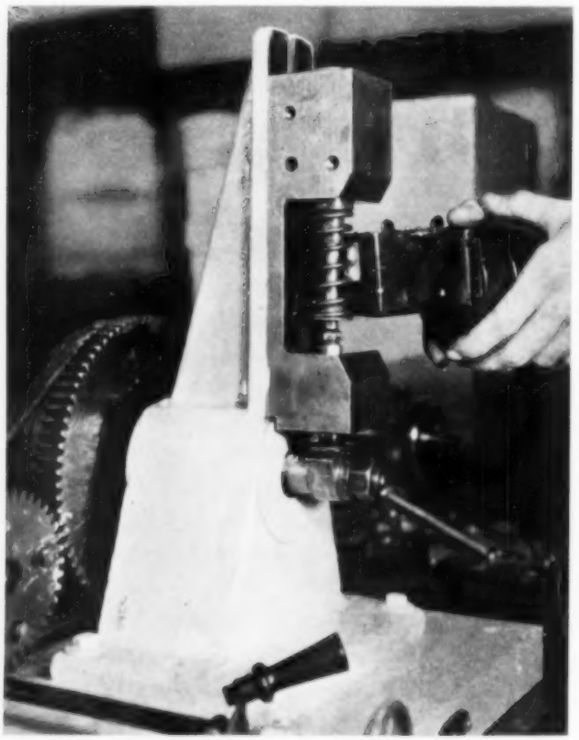
In order to obtain a spring of the best surge characteristics, it is general practice to make numerous samples having the specified load requirements but coiled with slight deviations in the pitch. The spring with the least amount of surge may easily be selected from such a series. However, such tests do not give the final answer as to the elimination of valve spring vibration, for springs must be observed, preferably by a stroboscope, in the engine at all speeds. The reason for this is the difference in the natural frequency of the engine block and the testing machine.

Other Factors Affecting Life

When a spring has been developed to meet all the requirements for design, material, and surge, it is ready to be installed in a motor for a life test. Other factors which seriously affect its life must now be investigated.

The effect of corrosion fatigue is very pronounced. Hot crankcase gases contain water vapor which condenses when it comes into contact with the valve springs (cooled by the nearby water jacket) and corrodes the wire. Weak sulphurous acid formed by the products of combustion is a contributing factor to this corrosion. The effect of corrosion on the fatigue life of a sample subjected to cyclic stresses is well known; the endurance is reduced to as low as one-sixth the expectancy had the test been carried out in dry air.

Corrosive conditions found in engines may be corrected in several ways. The preferable method is to improve the crankcase ventilation to a degree where the gases have a dew point below the cooling water temperature; under these conditions no condensation can occur. Corrosion of the wire may sometimes be materially decreased by increasing the oil spray into the chamber. This washes away the corrosive condensates and constantly renews the oil film on the surface of the wire.



Valve Spring Vibration Indicator (Recorder) Used on Valve Gear Set-up

An alternate method of eliminating corrosion is by plating the spring. Plating should be done only where the trouble cannot be eliminated by improvements in ventilation. An example is found in marine engines where cadmium plated valve springs are used.

Epidemics of failures have also been traced back to valve springs that had corroded during shipment or in storage. For this reason many manufacturers protect their springs from rust by coating them with a good rust inhibitor.

The accuracy of the height dimensions, as installed in the engine, is another important factor in the life of a spring. Cases are known where the accumulated errors, from the valve seat down to the retainer lock, have caused an increase of actual stress of 20% of the calculated maximum working stress. On valve springs this is usually beyond the factor of safety, and trouble is unavoidable.

After the final check-up of the spring's future surroundings and working conditions in the engine, life tests are started on a large number of springs made by production methods. Road cars, dynamometer and water brake engines with laboratory set-ups are equipped to obtain as much mileage as possible in the shortest time.

The laboratory life test machine consists of a universal set-up in which the valve gear mechanism may be operated day in and out under variable speed conditions inside a box where atmosphere and temperature may be controlled. Results from this machine have been correlated with road tests over a period of years, so if the laboratory results are satisfactory, the engineer is ready to release the spring for production.

The experimental engineer has now completed his assignment. Design, material and other factors affecting the life of the spring have been investigated. The results of development work, life tests and actual engine operation have been accumulated. The spring may now be expected to meet all the requirements placed upon it and should give satisfactory service.

by W. H. Eisenman
Secretary
American Society for Metals
Cleveland

Pennsylvania & Ohio chapters hold meetings

NESTLED in the foothills of the Alleghenies, directly in the center of the state, rests beautiful Pennsylvania State College. It was to this hospitable retreat that members of the American Society for Metals from the five Pennsylvania chapters — Pittsburgh, Philadelphia, York, Southern Tier and Lehigh Valley — wended their way on May 4 to attend the first group gathering of the state's chapters.

In former years several successful meetings had been held in the eastern part of the state, participated in by members and friends of the Philadelphia, Lehigh Valley, Newark, and New York Chapters, but this latter group has not met as a group for the last two years. Consequently, the all-Pennsy meeting was not only an innovation, but an indication that "Happy Days Are Here Again!" there being no less than 142 out-of-town members from 11 chapters registered at the Penn State Conference in May.

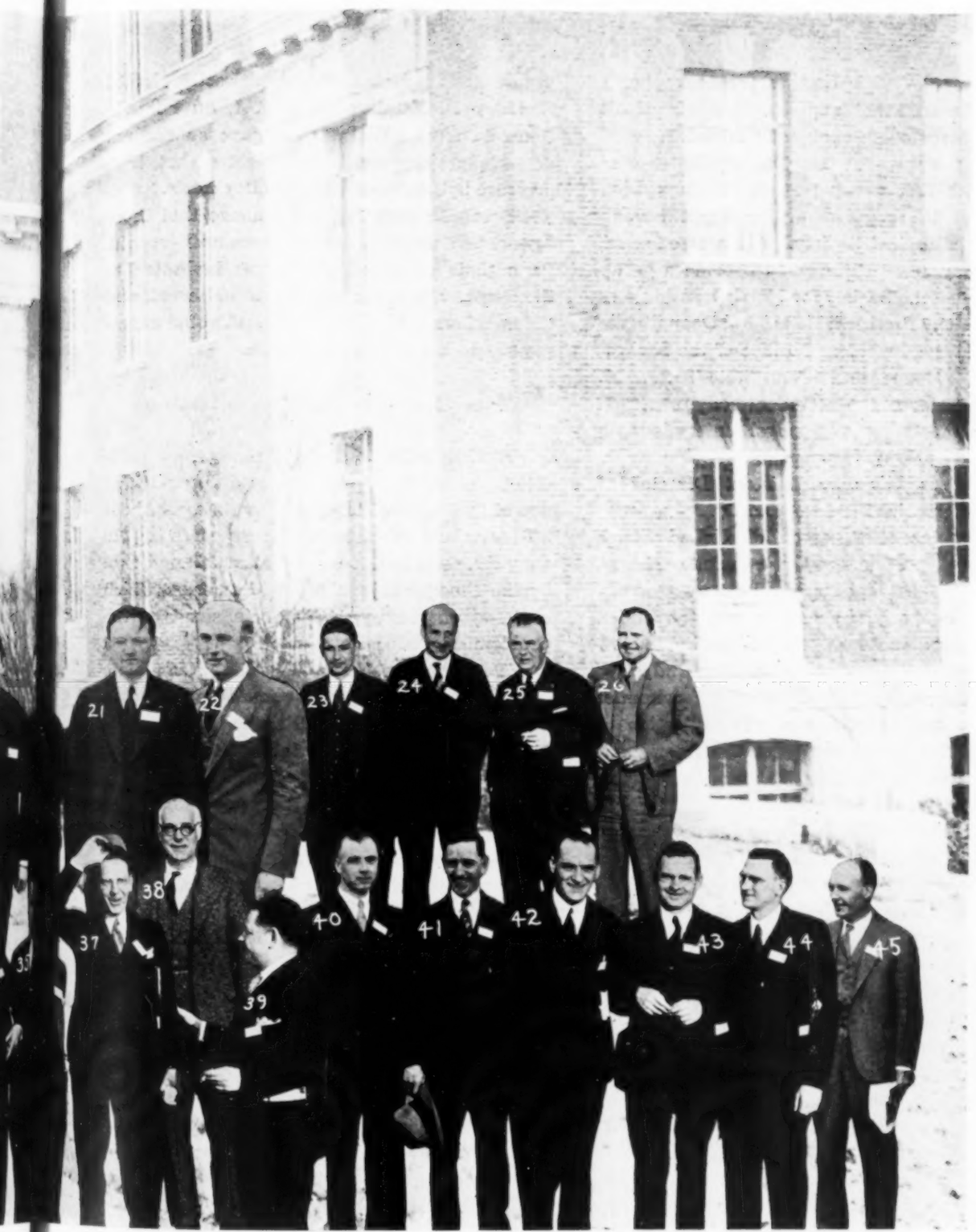
It may be interesting to recall some of the past history of such gatherings. Some years ago the American Society for Steel Treating held a series of semi-annual meetings, in late winter or spring in cities which did not have the proper facilities for entertaining the annual convention and National Metals Exposition. Such meetings were held in Davenport, Cincinnati, Montreal and others. While all of these brought together a group of men interested in current technical questions, they did not appear to interest enough members living at some distance to warrant the rather large expenditure. In other words, it appeared desirable to abandon such meetings as a "headquarters' effort" and to encourage regional meetings under the direct control and operation of the chapters involved.

That such a plan is an altogether happy solution of the problem was proved by the two meetings now to be described held about a month ago, one at Penn State and the other at Columbus.

The sponsor of the first-mentioned event was the School of Mineral Industries of Pennsylvania State College, under the capable direction and leadership of President Ralph Dorn Hetzel and Dean Edward Steidle, with D. F. McFarland, A. O. Knight, O. B. Malin, Jim Long, Harry Northrup, and Dave Dilworth, representing the metallurgical department of the school. The Nittany Lion Inn made an ideal headquarters for the visiting members. In its hospitable atmosphere the spirit of fellowship pervaded, where new acquaintances were made as well as old ones revived, and thus it lent itself admirably to one of the main objects of a group meeting of this character.

Our demon photographer, Past President Coleman, W. G. P., was loose, snapping right and left with his "candid camera." The groups assembled in one large engraving on pages 40 and 41 are proof enough not only of Bill's hon-

1—B. F. Shepherd
2—E. J. Poole
3—W. H. Phillips
4—John Johnston
5—O. E. Harder
6—T. G. Foulkes
7—B. H. DeLong
8—O. V. Greene
9—G. V. Luerssen
10—F. R. Palmer
11—J. C. C. Holding
12—V. N. Krivobok
13—N. A. Ziegler
14—O. B. Malin
15—Edward Steidle
16—A. C. Jones
17—H. T. Cousins
18—M. W. Dalrymple
27—E. H. Dix, Jr.
28—Maxwell Gensamer (See also 21!)
29—H. B. Northrup
30—G. B. Upton
31—O. A. Knight
32—Ralph D. Hetzel (Pres. Penn. State)
33—D. F. McFarland
34—T. H. Nelson
35—L. F.



Some of Those Snapped at Penn State

21—Maxwell Gensamer 22—W. I. McInerney 23—N. I. Stotz 24—G. E. Doan 25—Pres. W. H. Phillips (a second time!) 26—J. P. Gill

38—Bradley Stoughton 39—W. H. Eisenman 40—F. J. Allen 41—G. J. O'Neill 42—W. J. Diederichs 43—J. R. Adams 44—H. L. Maxwell 45—F. B. Foley

orary title ("World's Greatest Photographer") but of the informal and convivial air of all who were fortunate enough to attend.

Being a two-day session, a dinner was served the first evening at the Nittany Lion Inn under the auspices of the Student Penn State Metallurgical Society. (This association, by the way, has petitioned to become a group of the American Society for Metals.) Addresses were given by President Hetzel and Dean Steidle of the College, President Phillips of the Society, and C. W. Heppenstall (Penn State '95; A.S.M. '21). In the evening the student body presented a very interesting and novel entertainment, sponsored by C. W. Heppenstall.

Dr. Oscar Harder, Assistant Director of Battelle Memorial Institute, and Dr. John Johnston, Director of Research of United States Steel Corp., presided at the technical sessions. Each of the participating chapters was responsible for one of the speakers, with an added one for good measure. Dr. Johnston led off with a talk on "Research in the Steel Industry" based on the belief that the possible economies in manufacturing processes and utilization of raw materials were nearly achieved, whereas further lowering of costs must come in better quality of product. Frank J. Allen, Engineer of York Ice Machinery Corp., then spoke on "Steels — Their Selection and Application in General Shop Practice." This address will appear in a later issue of METAL PROGRESS. To complete the first session, E. H. Dix, Jr., Chief Metallurgist of Aluminum Research Laboratories, spoke on "Wrought Aluminum Alloys for Structural Applications," and described the uses of the metal as influenced by three fundamental differences between aluminum and steel: *(a)* One-third the weight; *(b)* one-third the modulus of elasticity, and *(c)* several times the cost.

Saturday morning, Prof. G. B. Upton of Cornell University spoke first, on "Decomposition of Saturated Solutions, With Particular Reference to Austenite." His paper was highly praised (by those who should know) as an important generalization of much experimental work reported to the American Society for Steel Treating in recent years. It doubtless will appear in *Transactions*. Vice-President Shepherd then spoke on "The P-F Characteristics of Tool Steel," along the lines outlined in the editorial in last month's METAL PROGRESS. Lastly, Harold L. Maxwell, Metallurgist of E. I. du Pont de Nemours & Co., Wilmington, gave an account of his experiences with the effect of hot, high pressure hydrogen on various alloy steels.

It can be seen from the above that those fortunate enough to attend were well repaid. Penn State extended a gracious invitation to the chapters to make this an annual event, and the members of the Society present voted unanimously to accept the invitation.

Ohio Chapters Meet at Columbus

A week prior to the above-described gathering, Columbus, Cincinnati, and Dayton held one of their annual tri-chapter meetings. About 240 members of the A.S.M., representing 16 chapters, were in attendance, attracted no doubt by the timely subjects under discussion which centered on the effects of grain size and the problem of grain size control.

A luncheon at the Faculty Club, Ohio State University, was enjoyed by about 50 out-of-town "early birds," who then adjourned to the auditorium of Battelle Memorial Institute. In the absence, because of sickness, of Dr. Charles E. Herty — who was to read a paper on steel making practice for controlled grain size — Dr. Harder, the chairman, called upon various plant metallurgists in the audience to describe their experiences. C. E. Sims, Metallurgist of American Steel Foundries, then discussed the effect and control of grain size in steel castings. His paper will appear in a later issue of METAL PROGRESS. Reid L. Kenyon of American Rolling Mill Co. then exhibited some interesting stampings, and explained the characteristics of the sheet required for their successful manufacture.

Dinner was served at the Columbus Athletic Club. After extemporaneous remarks by five officers of the National Society present, Prof. George N. Moffat, chairman of the Columbus Chapter, introduced the speaker of the evening — H. W. McQuaid — who discussed "Grain Size in Carburizing and Forging Steel." According to Harry, it was a dress rehearsal of his paper for the Annual Convention this fall — so those who were unlucky enough to miss the Columbus meeting can make a good recovery by coming on to New York!

by E. J. Esner
Apex Electrical Mfg. Co.
Cleveland

Modern metals used in household devices

ENAMELED sheet, die castings, case hardened screw machine products, and heat treated alloy gears are the principal varieties of metal parts entering into the construction of modern home laundry equipment. Present-day machines are the result of a considerable development in a highly competitive field, and some of the metallic materials mentioned above hold the positions formerly occupied by others, replaced because of a better combination of durability, appearance, and first cost. To bring out these points the latest model of "wringerless" washer made by Apex Electrical Mfg. Co., Cleveland, may be described.

In this machine a batch of clothes is washed in a stationary tub (a matter of 10 to 15 min.), the hot suds being dashed about by a screw-like agitator having a reciprocating rotation. Clean clothes are then transferred to a compartment alongside containing a smaller basket which is pivoted at the bottom and can be spun at a high speed. Centrifugal action dries the clothes; any number of rinses can be given in the same compartment while another batch is being washed. Action is entirely automatic except for opening or closing valves and loading the clothes into and out of the tub and drying basket. Agitator, centrifuge, and water pump are all driven from a single ¼-h.p. electric motor. It is obvious that a rather complicated drive with clutches, brakes, and safety devices must be provided. Finished dimensions on these parts of the equipment are held to tolerances of from half to two thousandths of an inch.

The external casing (legs, base, side panels, machinery guards) is all made of 18 g. ingot iron sheet — stampings spot welded together and coated with baked enamel in various attractive color schemes. The stationary tub, which occupies the large end of the casing, is also of enameled ingot iron — a seamless deep drawn stamping. For years copper was the preferred material for this part, but has been generally replaced because it was expensive, almost impossible to keep bright and shiny unless nickel plated, and the nickel plating would not survive many exposures to scouring cleaners. Baked enamel, on the other hand, wipes clean very easily, and the glassy finish can be made tough enough

so it will not chip unless it is badly abused.

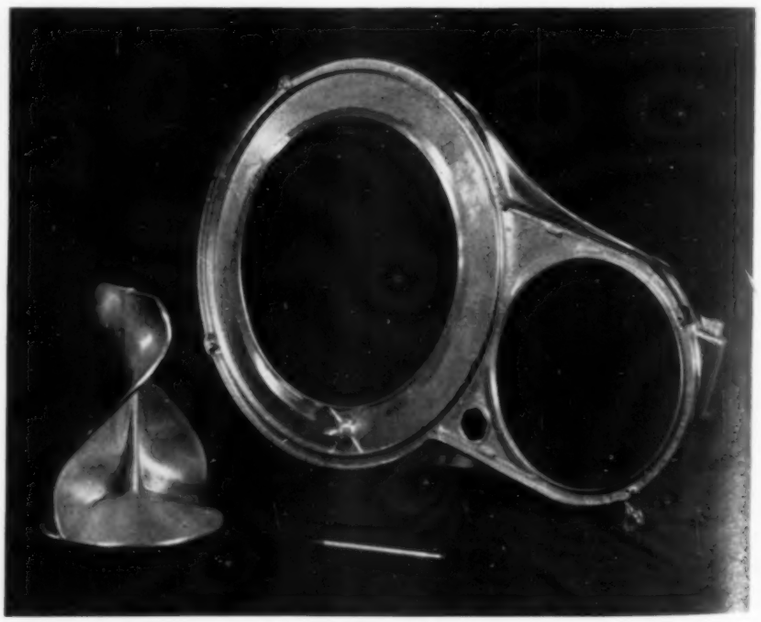
All exposed metal at the top is of aluminum sheet or castings. The main drip tray is interesting because of its size — 36 in. long by 24 in. wide at the widest part, and generally of thin section: ⅛ to 3/32 in. thick. When it was first put in production it was exhibited as the largest die casting then made in aluminum. The material is chosen because it polishes and buffs easily to a bright permanent color not affected by bluing or washing solutions, and because the castings are strong, light, and permanent in size and shape. Covers for the round opening over the washing tub are of stamped aluminum sheet, and over the rinsing and drying bowl are aluminum die castings. The latter had formerly been made of another material, but it required a cadmium plate to bring it to a good color match with the aluminum all about it, and this plating operation seemed to show up any concealed porosity in the casting.

The drying bowl or shell is itself an interesting example of cold worked metal. A piece of 12 g. aluminum sheet is drawn into a conical cup, 13 in. deep, 8 in. diameter at bottom and 11 in. at the top. Two dozen shallow channels, equally spaced, are then pressed into the sides in an expanding die, the center of the base punched out and the edge of the hole turned over into a bead and the corners rounded off by spinning. This rounded corner then makes the reinforced top edge of the drying bowl. The larger open end is closed by riveting on a zinc die-cast base for the bowl, which is really a centrifuge.

This part is of aluminum, whereas the tub is of enameled iron, principally because the method of construction (riveting) would crack or chip the enamel and cause unacceptable rusting.

Practically all shafting is made of S.A.E. 1020 cold drawn rod, machined to size on automatics, then case hardened, sandblasted, cadmium plated, and ground to 0.0005 in. tolerance on bearing surfaces. Sandblasting (in Sly wholly enclosed barrels) is found to increase the grinding speed materially; there is no oxide left to work into the emery wheels and foul them. All bare steel parts and screws and nuts which might get wet at any time are also cadmium plated to prevent rust. This plate is built up to 0.015 in. thick in a solution held at 5 oz. to gal. of cadmium and 16 oz. to gal. of sodium cyanide. Even springs for compressing packing about the agitator and rinse bowl shafts are cadmium plated. These must be cleaned in alkaline solutions before plating — acid cleaner will embrittle such hardened high carbon steels.

Cadmium plated steel was not satisfactory for the high speed shaft for the water pump. To improve matters the case hardened steel was then given a heavy chromium plate; while this did not rust quite so readily, it developed a high coefficient of friction with the brass bearings and packing glands, wearing out the latter too quickly. About three years ago a change was made to stainless steel of the original cutlery type (13.5% chromium, 0.35% carbon). In the softened condition this machines readily, so the manufacturing cost is small; the part is not very large (0.30x4¾ in.) so its raw-material cost is moderate; it resists soap and alkali cleaners



Large Aluminum Die Casting for the Washer Tub ("Drip Tray"), and Agitator Cast in Permanent Mold

Main Drive and Oscillating Mechanism For Wringerless Washer Contains Case Hardened Gears and Shafting, Zinc Die Cast Segments and Slides, All in a Cast Iron Gear Case

perfectly, so its service life is everlasting. It merely needs to be quenched to develop Monotron 50 hardness before grinding to shape.

More than usual care is necessary in making the bearings, glands, and fittings for passing the two vertical shafts through the water-tight casing. These must be permanently tight against leakage of water downward, or working of oil or grease upward. The pedestals, ball bearing cases, sealing nuts, and packing retainers are generally zinc die castings. Made of highest grade zinc these are strong enough for the duty, quite permanent in size and shape, and not affected in any way by the hot, soapy water. The ease with which very complicated and intricate parts can be cast to such close limits that no machining is necessary is an important factor in producing such household equipment at a price within easy reach of the ordinary citizen's pocket book.

The oil seal on top the bearing for the agitator shaft is an S.A.E. 1020 screw-machine part, hardened on the upper inside surface only, where it clears the shaft by 0.002 in. The differential hardening is done by copper plating the entire part, and cutting off the plate at the upper edge, where it is to be case hardened. The seal on the dryer shaft (which operates at a much higher speed) is a graphite-bronze duplex composition in the form of a simple ring. This is to be attached to a long bronze bearing (80-10-10) by soldering before final grinding of the assembly. In order to get a joint that oil will not leak through, the ring must first be given a light nickel plate, whereupon the solder "wets" the surface very satisfactorily and uniformly.

The Apex Electrical Mfg. Co. has its own foundry, and produces cast iron crank cases, gear segments, oscillator racks, brake cups and cones (to slow down the centrifuge bowl), main drive clutch parts, and such like. Some of these, like gear cases, which must hold dimensions accurately, are annealed at 1400° F. for 2 hr. In this same foundry many aluminum castings are made, both in sand molds and permanent mold. The largest of the latter is the agitator casting, a thing like a wide-sweeping auger; it is 13⅜ in. high and 10¾ in. diameter, of metal about ⅛ in. thick, weighing 3½ lb. It is rough polished with No. 80 emery and then wire brushed to attain a satin finish.

Many aluminum sand castings are also made which would probably be diverted to die castings (either aluminum or zinc) if the company did not have its investment in patterns and operating foundry. Those castings which

require a minimum of machine work can be economically produced in this way. Examples are lever handles (cast directly on steel bars), swiveling hot water faucet to serve either compartment, and pump impeller.

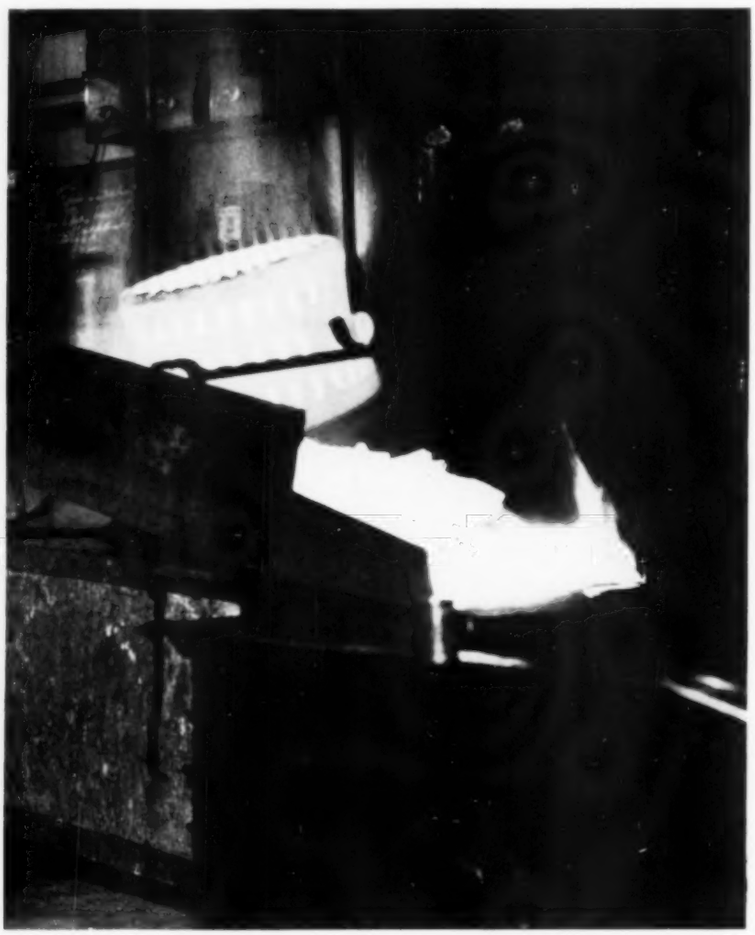
Nearly all of the water fittings are of brass —hose connections, valve stems, valve bodies —both for the fresh water and for the drains. Drains are protected by dome-like screens which are perforated zinc die castings.

A micarta gear is placed on the centrifuge shaft to avoid a drum-like magnification of sound by the outer casing. All other worms and gears in the various drives are cut from low carbon, medium manganese steel bars corresponding to S.A.E. 1315X. This material comes with a mill normalize, and we are able to cut about 250 gears per tool set-up, using a three-section gang cutter.

After the gears are cut they are carburized in gas, and oil quenched direct from the pot, cleaned and given 100% hardness inspection. After assembly in the gear cases, 100 of the latter are placed in a driving machine, for a 4 hr. run-in. The worms and mating gears are mounted in a fixture with centers accurately duplicating the gear case, and lapped together for perfect fit.

About five tons of steel parts are carburized every month — nothing special need be said about this practice. The medium manganese (S.A.E. 1315X) gears are carburized with a penetration of 0.015 to 0.017 in. per hr. in a natural gas atmosphere at 1725° F. For low carbon screw machine stock the rate of penetration is slightly less at the same temperature.

The view shows a pot load of small parts going down a slide into an oil bath. The 1315X will test Monotron 70 to 74 (Rockwell C-55 to 57) after quenching, and the 1020 will test Monotron 58 to 64 (Rockwell C-49 to 52). Parts that have to be Monotron 81 to 96 are carburized and cooled in the furnace, reheated to 1400° F. and water quenched.



Small Carburized Parts, Quenched Direct From Pot

Correspondence and foreign letters

Proper Terms to Describe Age-Hardening

TEDDINGTON, ENGLAND — In several recent numbers of the *Journal* of the Institute of Metals, attention has been called to the desirability of standardizing the nomenclature for age hardening. Suggestions have been put forward for a list of terms, some of which describe the processes employed, others the phenomena encountered. In order to treat this subject adequately the relationship of the terms used to describe recrystallization or softening phenomena should be compared with those suggested for age hardening (as these processes are very similar in their action).

The action of similar treatments on different materials may not always be alike in its effects, but attempts to describe phenomena similarly are likely to introduce uncertainties which may delay the development of the science. For example, the term "precipitation hardening" is not being correctly used when applied to other materials than those in which hardening is accompanied by visible formation of a precipitate under the microscope.

A most helpful contribution has been given by Dr. A. G. C. Gwyer; his list of terms, given below, possesses the advantage of simplicity. They also describe the treatment applied to the material. These terms include many of the details raised by other contributors to this problem:

Annealing is the operation of maintaining metal at a sufficiently high temperature and for sufficient time to ensure (*a*) Softening by removal of work hardness, with or without recrystallization, or (*b*) The removal of casting stresses.

Tempering is the operation of softening by means of heating to remove or diminish hardness due to previous heat treatment.

Solution treatment is the operation of heating with a view to taking a disperse phase into solid solution, with or without soaking.

Low temperature treatment is heating to some temperature below the quenching or recrystallization temperature.

Age hardening is the spontaneous hardening at room temperature with time.

Low temperature hardening is that increase of hardness due to low temperature treatment. The following fall into this category:

(*a*) Accelerated aging, or speeding up the hardening by low temperature treatment of an alloy which *will* age harden (at room temperature).

(*b*) Artificial aging, or hardening by low temperature treatment of an alloy which *will not* age harden (at room temperature).

It will be noted that these terms refer to the treatments given to the material and that they are free from the confusion which might arise from the use of terms applied to the phenomena likely to arise from these treatments. Included is the term *aging*, which (without the words "artificial" and "accelerated") refers to those processes which take place spontaneously at room temperature, as evidenced by either desirable or undesirable changes in properties.

A recommendation has also been made that

the term *modify* should not be applied to age hardening, but should be reserved for the structural refinement of cast alloys, such as results from the adjustment of casting conditions and the presence of addition agents (such as sodium in 13% silicon-aluminum alloys).

The usages described above do not clash with the special applications of the terms "annealing" and "tempering" to steel treatment, as can be seen by consulting page 251 of National Metals Handbook, 1933 edition. The terms as now set forth adequately describe the process of age hardening in the alloys of aluminum, copper, lead, and iron. It is to be hoped that some such list as the above will prove acceptable to metallurgists in both America and England and that the scientific and technical societies of other countries will define the terms in a somewhat similar manner, and that writers and editors will adopt them.

C. H. M. JENKINS

Turning Old Armor Plate Into Forging Dies

GROSNY, U.S.S.R. — The industrialization of the Soviet Union and development of an automobile and tractor industry has created a demand for quality alloy steels, including steels for forging dies, far beyond the capacity of our own works capable of making fine steels. Import is handicapped by lack of finances and the result is a certain deficit of alloy steels in this country, yet up to the present time the requirements for high quality die steels have been met to a reasonable extent by import.

A point of special interest which is to be discussed here, is a new source of such material, namely, old armor plate taken off warships which were wrecked during the War, and supplies of unused armor steel from the naval arsenals. American engineers are doubtless well informed about the extensive salvage operations undertaken by an English firm whereby the surrendered German fleet, scuttled in Scapa Flow, was raised. In our own country a less extensive effort by a Submarine Works Expedition raised a number of wrecked ships in coastal waters, so that their metal and equipment might be made use of.

This gave us a large supply of old armor from 3 to 10 in. thick, the most of which was sold abroad, as no use could then be found for it except in the oil industry for drill bits.

Some Soviet metallurgists recommended its use as scrap for remelting in open-hearth furnaces into alloy steels. Others held it more rational to manufacture die blocks from them, first annealing the entire plate and then cutting out blocks of proper size with an oxy-acetylene cutting blowpipe. This latter proposition is now being carried out in practice.

Chemical composition of the armor steel under discussion is analogous to certain steels used abroad for hot dies. It is a nickel-chromium steel whose composition varies, plate to plate, within the following limits:

First sample: Carbon 0.31%, chromium 2.3%, nickel 3.9%, manganese 0.39%, silicon 0.02%. Second sample: Chromium 1.08%, nickel 2.5%, manganese 0.56%, silicon 0.23%.

Such steel self-hardens throughout the whole mass upon cooling in open air to Brinell 450 to 500, and at the same time retains considerable toughness. It therefore possesses many advantages over the plain carbon die steels, which harden only to a certain depth of penetration.

The mechanical properties of some samples of annealed armor are as follows: Tensile strength 130,000 lb. per sq.in., yield point 110,000 lb. per sq.in., elongation 12% in 10 dia., reduction of area 60%, Charpy impact 4.1 kg-m. per sq.cm.

After quenching in oil at 1515° F. and tempering at 930° F., the ultimate strength was 190,000 lb. per sq.in., yield point 175,000 lb. per sq.in., elongation 9%, reduction of area 44%, and Brinell hardness 500 to 550.

In service the dies manufactured from armor steel give eight or nine times more forgings (about 5000) than the dies manufactured from plain carbon die steel. In very severe service on automobile valves, armor steel dies produced 15,000 forgings.

Success has been so great that the existing supplies have been commandeered by the Commissariat of Heavy Industries for the above described purposes and will thus be very valuable in the present emergency.

B. M. SUSLOV

Value of Sponge Iron as Raw Material for Steel

SCHWEINFURT, GERMANY — Manufacture of iron direct from its ore has always been of the greatest interest to European metallurgists, especially in Germany and Sweden. A project for the construction of a plant in Germany received a great impetus in 1927 when F. Wüst, the Nestor of iron and steel metallurgists, warmly sanctioned the project. The considerations which led to a final decision were reflected in an article by Dr. Rohland in *Stahl und Eisen*, 1929, page 1477. His investigations led him to the following general conclusions:

1. Mild steels. Sponge iron in the charge in either small or large percentages should improve the machinability and other fabricating characteristics, for red shortness and cold shortness were never found. Workability and plasticity were excellent. Good magnetic properties were likewise obtained and the aging properties of quenched steel melted from sponge iron were better than those of steel melted from scrap.

2. Plain carbon tool steel with low manganese and silicon content. Steels of this type made of sponge iron possessed superior hot working qualities. Solution of pearlite was rapid during annealing. The hardness range was very good. The hardened zone was also distinctly marked from the unhardened core, and the tendency to break along this boundary was suppressed.

3. Plain carbon tool steel with normal manganese and silicon content. Such steels melted from sponge iron had particularly good hot working qualities. Cold working qualities were also excellent when rolling to strip. Steels in this group also acquired a faster rate of soft annealing. Wear and toughness tests were satisfactory.

4. Special chromium steels. These steels have excellent toughness, because the grain is refined by the use of sponge iron.

5. Special tungsten steels have a wider hardening range when melted from sponge iron, but the magnetic properties are not particularly good.

From the experimental results briefly outlined above on steels melted from sponge iron, Dr. Rohland came to the conclusion that the high speed of solution of pearlite, as well as their broader temperature range in heat treatment, was characteristic of their quality. An explanation for this improvement in quality was sought "only in the unused condition of the raw material" — Wüst described it as due to "the virginity of the charge."

Leading German metallurgists discussed Dr. Rohland's detailed report, and all were not convinced that all the improved properties cited could be generally attributed to the use of sponge iron. E. Houdremont placed cost as among the important considerations. His opinion agreed with that of most of the metallurgists when he said: "Sponge iron will be very welcome to us as a steel-making material of the highest quality, especially if it should be less expensive than other high quality materials."

In order to determine the true facts, a large research plant was erected in Bochum in 1929 by two leading organizations (Fried. Krupp A. G. and Vereinigte Stahlwerke A. G.) for the manufacture of sponge iron by the Norsk Steel Co. process. The method used and the results obtained were given publicity by means of a lecture by E. Edwin in Essen and a report by Ivar Bull-Simonsen in *Stahl und Eisen*, 1932, page 457.

Bull-Simonsen was of the opinion that the manufacture of steel from sponge iron cannot be cheaper than when pig iron from the latest type of blast furnace is refined in ordinary steel furnaces. Sponge iron manufacture, however, is warranted by the superior type of steel it produces from a very pure raw material. Requirements at the Bochum plant were that phosphorus and sulphur together should not equal more than 0.025%, and that the degree of reduction in the sponge should be at least 90% with a minimum iron content of 92 to 94%. These conditions were fulfilled, with a few exceptions when the reduction was less than 90%. The carbon content averaged 1.2% and was very uniform in all samples. A day's production, using Sydvaranger briquettes, averaged 85,000 lb. The plant operated at about 10% under the expected production.

The technical difficulties attendant on the large scale manufacture of sponge iron by the Norsk Steel Co. process may now be regarded

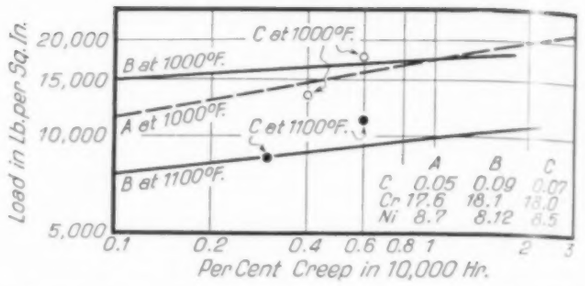
as finally overcome. Because of the economic crisis, however, the cost of production at Bochum has been so increased that the development program has unfortunately been abandoned, and is dormant at the time of writing. It is hoped that the scheme will be revived in another location, where the cost of the necessary electric current is lower than in Germany.

Our metallurgists are following this question with the greatest interest, as is best reflected in the large number of patents issued and in the ever-increasing amount of discussion in the literature about technical and economic problems involved. We are convinced that these preliminary troubles in the sponge iron industry can be surmounted and the use of sponge iron will increase, for good raw material is the basic requirement for good steel.

HANS DIERGARTEN

Creep Strength of 18-8 After Four Years' Service

CAMBRIDGE, MASS. — An excellent opportunity occurred recently to determine the effect of service on the creep resistance of 18% chromium, 8% nickel alloy. A 4-in. tube with a ¼-in. wall was removed from an oil cracking still after four years' service with about 90% continuous operation. The total time at an operating oil temperature of 825 to 875° F. amounted to 31,100 hr., during which period the pressure varied between 500 and 700 lb. per sq.in. The actual tube temperature was stated to run between 925 and 975° F., but probably ran higher at times, when coke built up in it.



Creep Percentages for Used Boiler Tubes Plotted Against Curves Derived From the Material Before Use

The position of this tube was next to the side wall in the second row from the roof in the radiant section of the still. This tube was the 15th tube from the outlet, while the radiant section was four rows high and 14 rows wide.

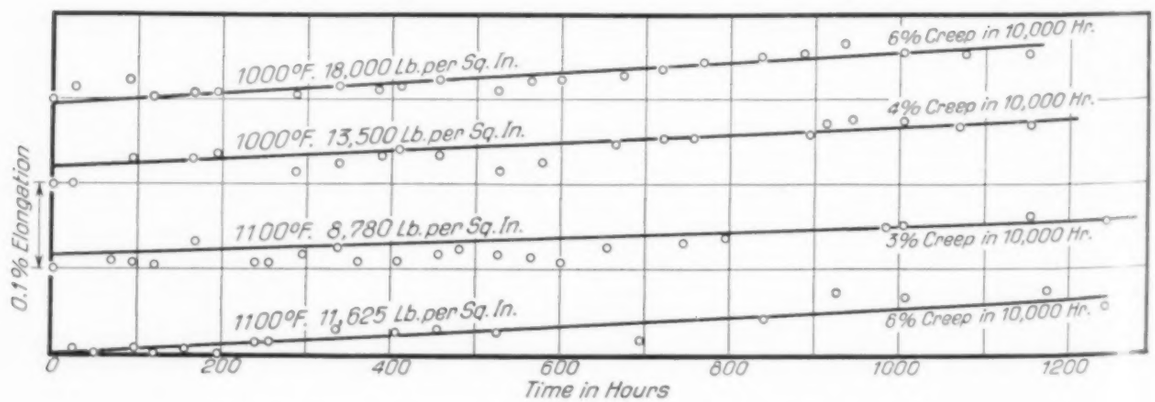
The specimens for creep testing were cut longitudinally from the tube and were not heat treated in any way before the test.

Chemical analysis of the tube material when removed showed the following: Carbon 0.072%, manganese 0.47%, silicon 0.35%, chromium 17.98%, and nickel 8.46%.

Physical properties at room temperature showed: Ultimate strength 99,600 lb. per sq.in., yield point 51,200 lb. per sq.in., elongation in 2 in. 43.5%, and Brinell hardness 177.

The microstructure showed some alteration from the original material, due to carbide precipitation, but there were no evidences of intergranular corrosion; therefore it apparently had suffered no structural deterioration. Some cold work was in evidence along the inner wall, due to numerous cleaning operations with a turbine cleaner throughout its life.

The creep tests were made under my di-



Time-Elongation Curves for Samples of Four-Year Old Tubes of 18-8

rection at the Massachusetts Institute of Technology for the Babcock & Wilcox Tube Co. with apparatus employing a 2-in. gage length. The testing temperatures were 1000° and 1100° F. The time-extension curves for the various loads are shown herewith. Flow rates as determined are plotted on the smaller diagram to compare them with data derived from the original steel.

It will be apparent that the creep resistance of this 18-8 material has not been affected in any way during its long period of service, and these results should give designers definite confirmation of the stability of this material over long periods of service.

F. H. Norton

Boundaries Between Iron, Steel, and Cast Iron

PARIS, France — The definitions of iron, steel and cast iron given in the report by H. M. Howe and A. Sauveur to the International Association for Testing Materials, New York, in 1912 (as well as the earlier ones) are all based upon the properties of these materials and the conditions under which they were then obtained. For example:

Iron (*fer*) was characterized by its plastic origin, without melting (such as the puddling process for wrought iron).

Steel (*acier*), on the other hand, was obtained in the liquid state. A further limitation was that it must be malleable, at least between certain temperature limits. Its ability to be hardened and tempered was also considered as one of its essential and distinctive properties.

Cast iron (*fonte*) was characterized both by its liquid origin and its want of malleability at any temperature; some authorities believed that it should always contain a considerable percentage of carbon — more than 2.5%, say.

The above definitions, which were a great advance towards a scientific nomenclature, were criticized by some metallurgists, more particularly the English. It was pointed out that "blister steel" (carburized bar iron) was made without passing through the molten state. Other objections referred to malleableized cast iron, which will bend or stretch considerably before failure — a property which does not belong, by definition, to cast iron.

Such ambiguities have been increased in the intervening years by improvements in melting and refining processes, new electric furnaces capable of high temperatures, and by the considerable increase in the number and diversity of the manufactured products, all essentially iron-carbon alloys.

Thus ingot iron (*fer fondu* or *fer en lingots*) is now manufactured in large tonnages, and Prof. Sauveur, himself one of the protagonists of the above definition for iron, thinks that Armco ingot iron, though it is obtained through a liquid bath and cast into an ingot, must be called iron and not steel. "It would be absurd," he says in *Revue de Metallurgie*, 1923, "to call *steel* the purest iron which has ever been produced industrially simply because it was manufactured in a furnace used for the production of steel."

Neither does the distinction as to malleability exist, as it may be said that tool steels containing high tungsten and high chromium are less malleable than the low carbon cast irons now on the market. (The latter also transgress the older ideas as to chemical analysis, as many have a lower percentage of carbon than 2½.)

Furthermore, it is merely necessary to mention that the ability to harden, formerly considered a sole characteristic of steels, is very common — all of the iron-carbon alloys are capable of a martensitic hardening, except those akin to pure iron.

Therefore, none of the characteristics which were the basis of the early definitions remain as valid distinctions — a situation resulting, for the most part, from the qualitative character of the criteria originally relied upon. For example, malleability of steel may have all possible values — and these are not well defined and depend upon the operating conditions.

Such a situation always will exist whenever a continuous series of phenomena must be sub-divided before it is possible to evaluate them numerically and set up, by convention, certain limiting values. We must face today the situation that all the manufactured products merge by almost insensible gradations and all of them are obtained in the liquid state.

The only numerical characteristic that remains invariable for the same alloy whatever be the mechanical and thermal history is the elementary chemical analysis. The chosen definitions must consequently be based upon chemical composition, so that one may analyse the metal to decide borderline questions. Such definitions should also state or imply the historical characteristics of malleability and hardening capacity.

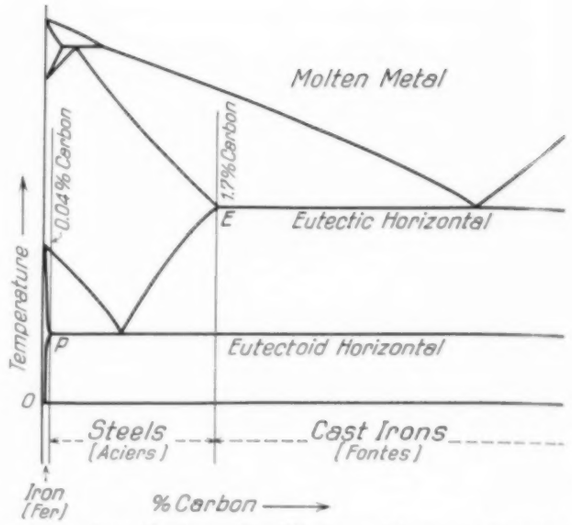
Precise definitions may be devised with the aid of metallography, which has now become fairly familiar to the metal industry. They should also follow the principles of pedagogy — to be plain and clear without relying on a body of workshop experience. Therefore, I will now state some definitions adopted some years ago by me for teaching purposes:

Cast iron is a carburized product presenting, or capable of presenting, some eutectic after solidification. This eutectic contains cementite in white cast iron, and is a lamellar graphite aggregate in gray cast iron. Cast irons at the moment of solidification are therefore essentially what Howe would term eutectiferous products. When they contain but little of any other element than carbon, the latter must be more than 1.7%. This limiting content may vary as other chemical elements are introduced, but it may be defined by metallography and chemical analysis. As the cells of cementite eutectic (or the graphite grains) impede plastic deformation, these products are but slightly malleable or not at all.

Steel is a carburized product with no eutectic, but one which undergoes a eutectoid transformation giving birth to pearlite. Steels may be divided into hypo-eutectoid and hyper-eutectoid. As cast irons and steels all contain austenite which transforms into eutectoid, they may undergo the martensitic hardening.

Iron is a product in which the eutectoid transformation is lacking and consequently shows no pearlite in the microstructure. In pure iron-carbon alloys this will occur if carbon is less than about 0.04%. No martensitic hardening will occur on quenching; however, a structural hardening may occur because of the traces of carbon present, or the presence of other elements — nitrogen, for instance.

These three definitions are clearly indicated



Iron-Carbon Equilibrium Diagram Showing Limiting Analyses for Iron, Steel and Cast Iron

on the annexed equilibrium diagram. The two points *P* and *E* mark the limits; they correspond to something real and defined. On the whole, such boundaries are consistent with the properties formerly considered as characteristic — that is, malleability and hardenability — and at the same time fully explain them.

A. M. Portevin

"Body" of Ale, Bar Iron and Tool Steel

MONTREAL, Canada — Readers of Mr. Lantsberry's article in the March number of Metal Progress and the editorial last month may be interested in knowing that the term "body" was applied to steel years before Benjamin Huntsman first cast steel in Sheffield. The oldest book in my small collection is "L'Art de Convertir de Fer Forgé en Acier" by René Antoine Ferchault de Réaumur, published in Paris in 1722. The newest is "Steel Makers" by Harry Brearley, London, 1933. In both of these "body" is dealt with at some length!

Réaumur in his tenth memoir "On the Methods of Discerning the Defects and the Good Qualities of Steel" tells us that the good qualities can be reduced to three principles, the third of which is "the disposition to retain, after quenching, more or less body."

According to Mr. Lantsberry, users of the word body cannot define it in scientific terms;

nor, apparently, can the practical man define it in plain, good English, even though there has never been any doubt in his mind as to what constitutes body. Réaumur was troubled by no such inability, although the property which he called *le corps* 212 years ago may not be the attribute of steel which the practical man of today calls *body*. Réaumur wrote "The word body is ordinarily used to express the property which a hardened steel possesses of resisting the force which tends to break it. . . . . It always expresses a kind of toughness which the steel retains in spite of the hardness which it has acquired by quenching." (I have translated the French word *souplesse* by *toughness*, though my French friends here tell me that the exact meaning which *souplesse* conveys to them is "the opposite to brittleness.")

In Réaumur's pages which follow this definition he has much to say about body. "Of the three essential qualities of steel, body is that of which the determination. . . . ." "To decide which of two steels has more body." "I know that this steel has more body than the other." And so forth.

Mr. Brearley applies the word body not only to steel, but to two of the raw materials used in its manufacture — ale and wrought bar iron. Fifty years ago, he tells us, one of the most important duties of the cellar-lad in a Sheffield steel works was, and possibly still is, the fetching of ale for the furnacemen, whose coefficient of absorption was usually high, and in some cases phenomenal. From time to time the lad would be instructed to exclude a certain ale-house, not always the same one, from his sources of supply because the beverage on draught there was all arms and legs, and in consequence sadly deficient in body!

We search in vain, however, for any statement that the body present in either, or both, of these raw materials of steel-making is inherited by the steel made therewith. Indeed, the reverse is more than suggested, for we read "If 'body' is supposed to be a desirable something in certain brands of Swedish bar iron, then it can be shown that this inherent something may not survive the melting and forging operations, and can fail to appear in the finished tool steel."

Mr. Brearley tells us that tool steel is now manufactured by firms with experience, trained staffs, research facilities and large resources of capital. Is not the present situation (one might almost write *confusion*) concerning body, timbre, pedigree, personality, background, dependability, or inherent hardenability a direct challenge to these trained staffs with their research facilities? BERNARD COLLITT

Speculum Metal Castings

WASHINGTON, D. C. — Castings of speculum metal can be highly polished and have been used for many years as mirrors for optical instruments and as surfaces on which the closely spaced gratings for producing diffraction spectra are ruled.

The great telescopes of Sir William Herschel and of Lord Ross employed speculum mirrors, and contemporary accounts refer to the extreme difficulty of casting and finishing this alloy.

Good speculum metal should be perfectly white without a tinge of yellow, have a fine-grained fracture, be sound and uniform and sufficiently tough to grind and polish without danger of breaking. The most satisfactory composition has been found to be 66.6% of copper, and 33.4% of tin; by increasing the copper the color shades gradually into yellow. An increase in the tin, besides producing a blue color, renders the alloy very brittle so that it cannot be ground or polished satisfactorily. Even today considerable difficulty is encountered in obtaining a speculum metal casting having a cast surface satisfactory for polishing and free enough from internal stress so the castings will not crack while cooling in the mold or while being polished.

Development of the proper foundry technique has required considerable experimentation. A procedure giving satisfactory results consists in melting the virgin copper in a gas-fired crucible furnace under a cover of charcoal and adding the tin after the copper has become molten. 0.5% zinc is added to the molten metal as a deoxidizer before removing the crucible from the furnace. The temperature at which the metal is cast depends upon the size of the casting — 1750° F. is a good pouring temperature for castings 6x6x1 in. Green sand molds made from a grade 00

Albany molding sand are used, the surfaces of which are coated with a mixture of rubber cement and Ceylon graphite (ordinary mold facing materials are not satisfactory in producing the desired smooth surfaces).

Castings are allowed to cool in the sand mold through the solidification range and are then removed from the mold and placed within a hot furnace and cooled to room temperature over a period of 18 hr. This slow cooling insures a minimum amount of internal stress, which under ordinary treatment causes the cold brittle casting to break.

C. M. Saeger, Jr.

European Tool Steels Vary Somewhat from American

TURIN, Italy — The information on American tool steels, contained in Mr. Emmons's very interesting article published last December, shows many noticeable differences from the tool steels generally used in Europe.

In the class containing low percentages of alloying elements, the high carbon steel with 0.15% chromium is seldom used in Europe. On the contrary, one containing 0.6% chromium with 1.1 to 1.2% carbon is much used. In the same class, two other compositions are popular over here: A high carbon steel with 0.6 to 0.8% tungsten and 0.15 to 0.25% vanadium; another containing 0.6% tungsten, 0.6% chromium, and 0.3% vanadium. This last analysis is widely used for non-deforming tool steels, when it contains, in addition to the three elements above quoted, from 1.5 to 2% manganese; this last percentage is higher than the one quoted by Emmons for non-deforming steel.

In a second class, which might be called intermediate alloy steels, the compositions more commonly used in Europe are as follows: (*a*) 1.20% carbon and 1.0% tungsten, and (*b*) 1.20% carbon, 1.0% tungsten and 1.0% chromium. Tools made from them are never called "semi-high speed steel tools," this name being used for steels containing from 8 to 10% tungsten, 0.6% carbon and 2 to 4% chromium. However, such "semi-high speed steels" are practically disappearing from the market. The fact that they are not mentioned by Emmons seems to prove that they have already practically disappeared from, or never existed on the American market.

Differences between the American and European practice are more considerable and more general in the field of high speed steels, properly so called.

A first general remark may be made concerning the chromium content: Emmons's article does not list chromium contents higher than 4%. In European high speed steels the standard chromium content is generally 4.5% and often runs from 5 to 5.5%.

Our most widely used high speed steel is the "18-4.5-2" (18% tungsten, 4.5% chromium, 2% vanadium). This steel should therefore correspond in the European market to the 18-4-1 quoted as the most favored in America.

A similar remark can be made as to the carbon percentages, which appear to be generally higher in European than in American high speed steels. Emmons states that for general purposes carbon contents are from 0.60 to 0.75%, while steels with carbon contents from 0.70 to 0.80% are used where a high degree of hardness is required, and where high toughness is not essential. Compare this to general practice in Europe, where carbon contents lower than 0.70% are very seldom used, and 0.85% is frequent; normally it is from 0.72 to 0.80.

Steels with high tungsten contents (from 20 to 23%, and even up to 28%) have been used over here for some time. They are gradually disappearing, owing to the fact that the greater difficulty of hardening them properly is not counterbalanced by a real superiority of quality.

Recent European efforts to produce a "super" high speed steel have taken the somewhat different direction of an increase of cobalt and molybdenum contents. Emmons's sentence "Some steel makers add about 1% molybdenum to their 18-4-1 steels, especially if they contain cobalt, but the results obtained from it are not very apparent" would not be approved by European manufacturers. Their general opinion is that the increase of the normal 0.3% molybdenum content to 1% materially improves the hardening qualities and the resistance to wear. Furthermore, cobalt has been increased in the last few years, sometimes much above the upper limit of 14% noted by Emmons. Some large users have adopted high cobalt steels for all their tools. Federico Giolitti

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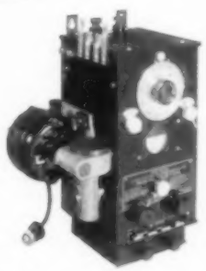

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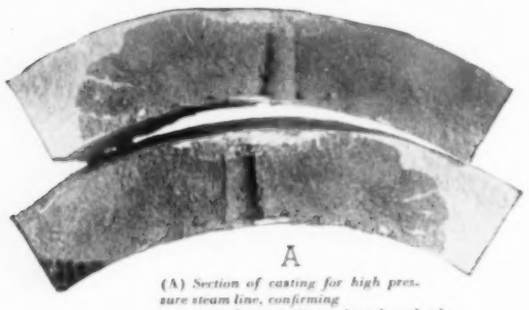
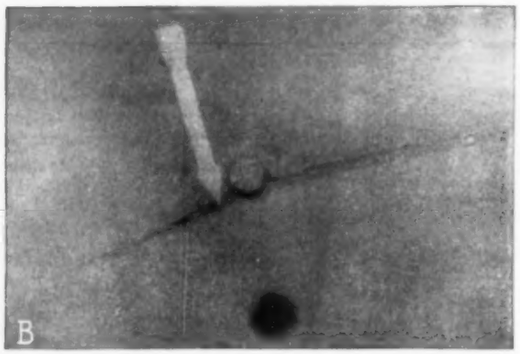


A

(A) *Section of casting for high pressure steam line, confirming*
(B) *X-ray findings of crack at chaplet, indicating faulty casting technique.*



B

X-ray vs or + saw

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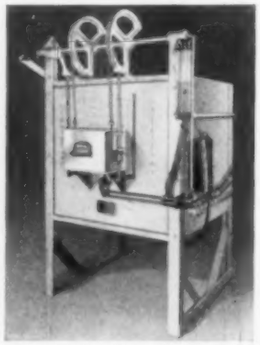

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